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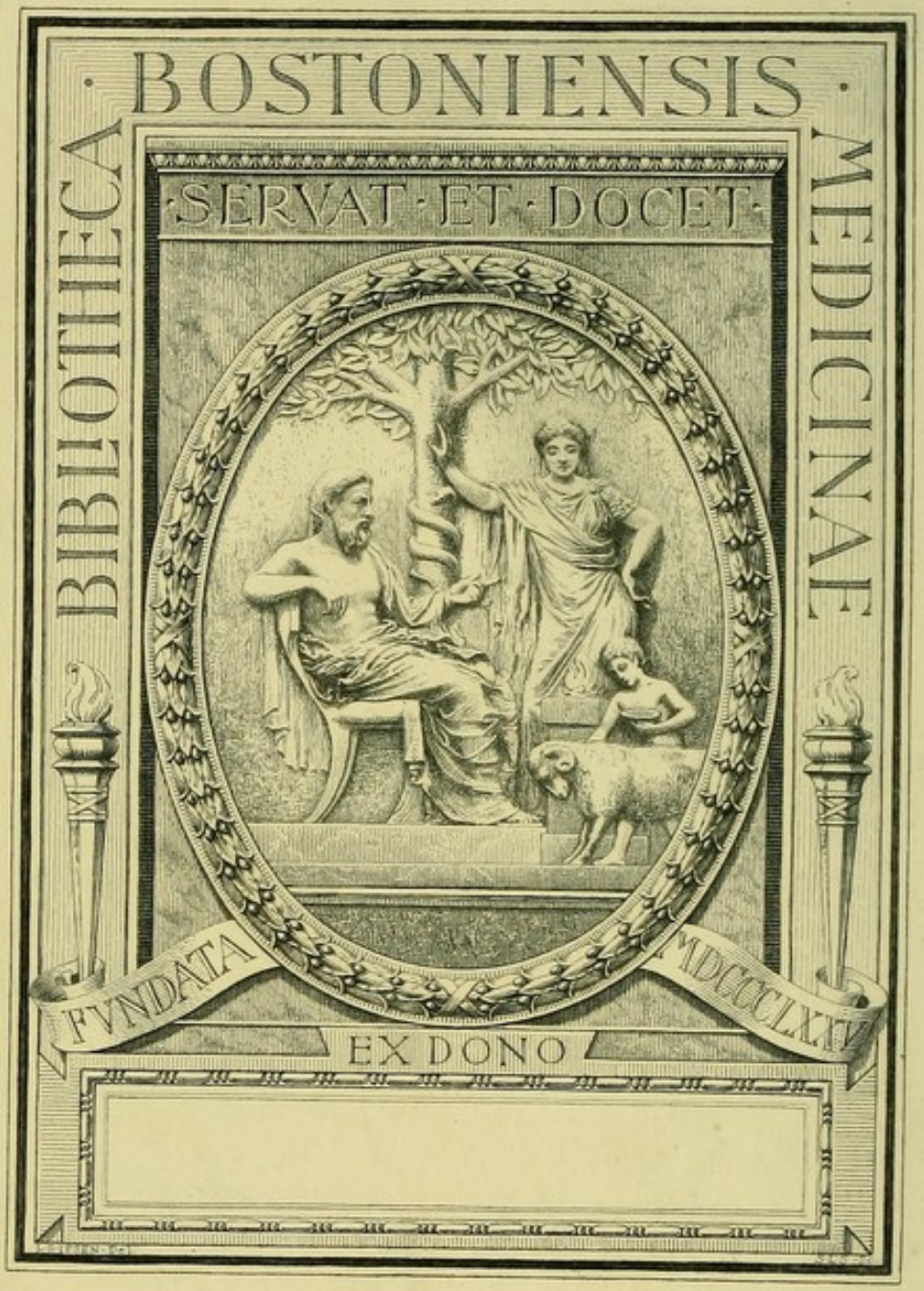
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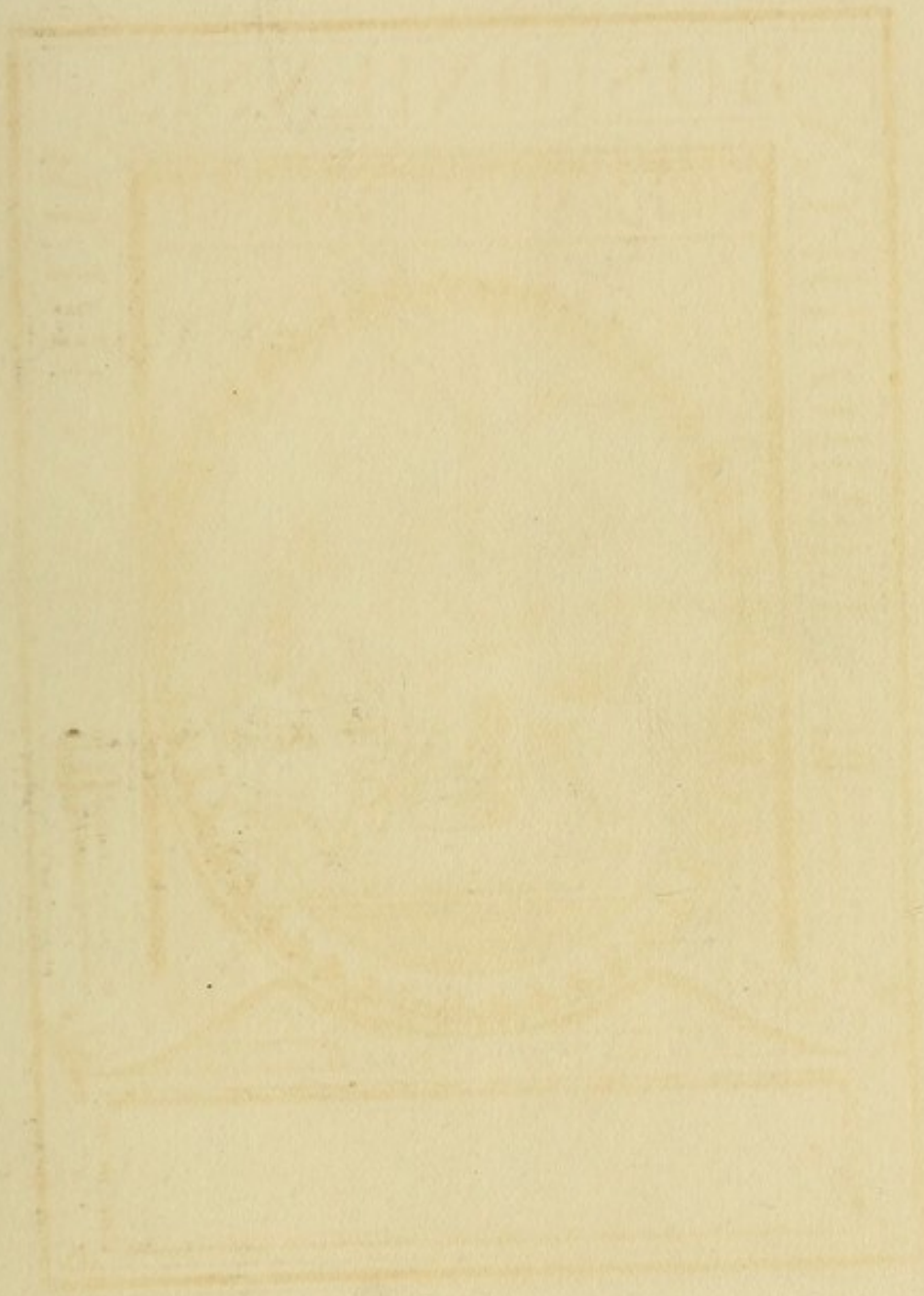
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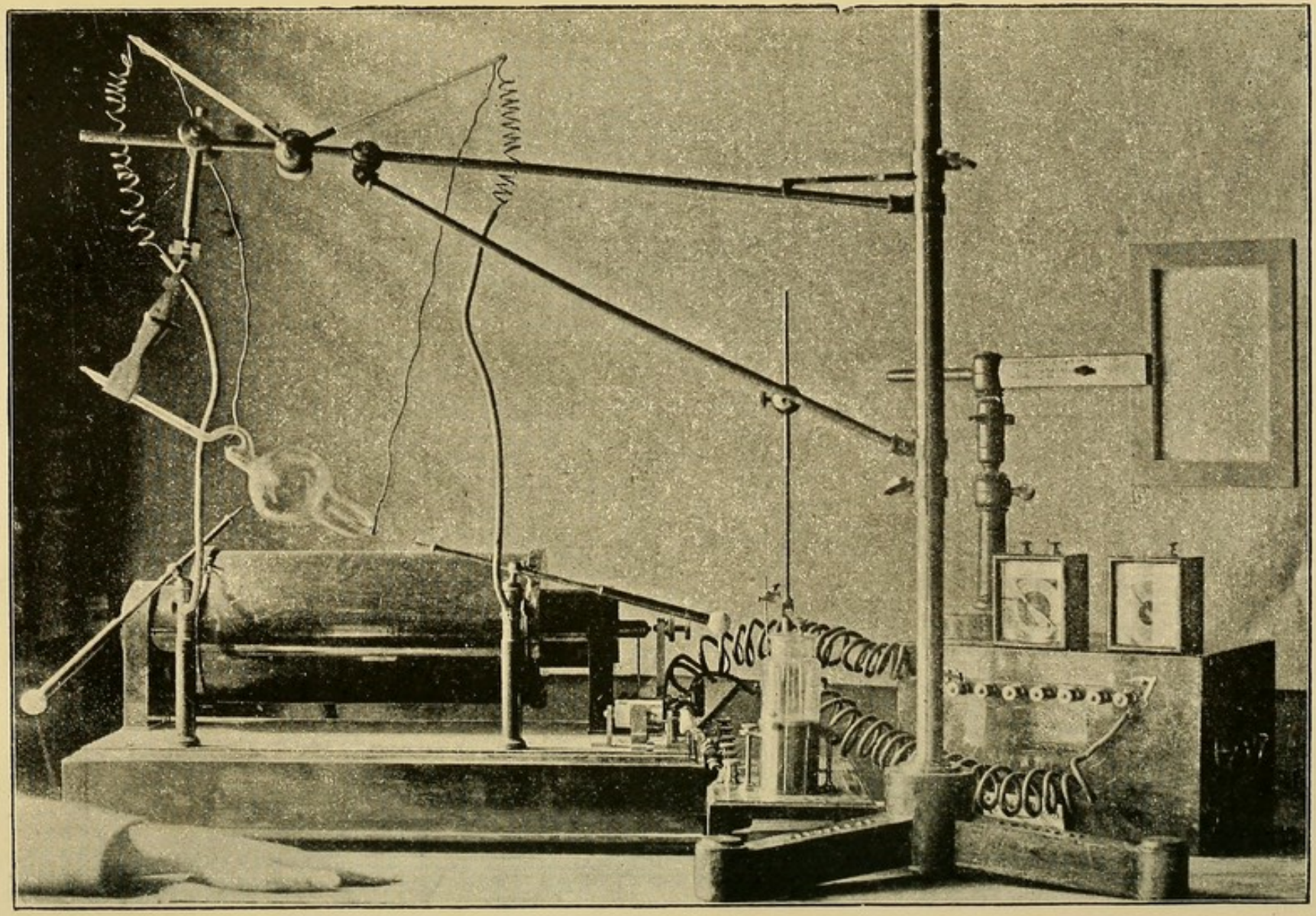


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THE RÖNTGEN RAYS IN MEDICAL WORK

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Complete Apparatus (in 1902) for Röntgen Ray Work, consisting of Secondary Battery, Voltmeter, Ammeter, Induction Coil with Ordinary and Mercurial Break, Focus Tube, Fluorescent Screen on Stand, and Hand in Position upon Photographic Plate.

THE RÖNTGEN RAYS IN MEDICAL WORK

BY

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PART I.—**THE ELECTRICAL APPARATUS**

BY

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MEDICAL OFFICER IN CHARGE OF THE ELECTRICAL DEPARTMENT, ST. BARTHOLOMEW'S HOSPITAL

PART II.—**MEDICAL AND SURGICAL**

BY THE AUTHOR

φάος κάλλιστον τῶν προτέρων

FOURTH EDITION

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WILLIAM WOOD & COMPANY
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PREFACE TO FOURTH EDITION

THE third edition of this book has been out of print for some years, and a fourth has been prepared at the request of the publishers.

The rapid increase of *x*-ray literature has rendered it no small task to keep abreast of recent advances. In this way some injustice has been done to the excellent work of Dr. Lewis Jones, dealing with apparatus and methods, which was written some time before the completion of Part II. Some difficulty of the kind, however, must necessarily be encountered in dealing with wide and progressive work that is every day breaking fresh ground.

The present edition has been enriched with a number of beautiful illustrations, in great measure due to the kindness of Mr. Robert Jones, F.R.C.S. The Author begs to tender his thanks to that gentleman and to many other friends and correspondents in various parts of the world for much kindly and valuable assistance in the preparation of this volume.

D. W.

LONDON,
February, 1907.

PREFACE TO THIRD EDITION

In this edition the Author has had the invaluable help of Dr. Lewis Jones, who has re-written Part I. The purely medical and surgical aspects of the subject have been brought up to date by an appendix added to Part II. of the second edition. Should this little work attain the dignity of another edition, it is hoped that the whole of the illustrations will be raised to the high standard of the best modern work.

D. W.

London, W.

PREFACE TO FIRST EDITION

SINCE the famous discovery announced by Professor Röntgen at the end of the year 1895, a new science has sprung into being. This branch of knowledge, although still in its early and undeveloped stages, has found a special application in medical work.

In this little volume the aim has been to deal with the present practical scope of the Röntgen rays so far as physicians and surgeons are concerned. An attempt has been made to treat the matter systematically, and to point out limitations and possibilities, as well as to record actual achievements. In this endeavour the Author has received invaluable help from Mr. J. E. Greenhill, who has also kindly written an introductory part dealing with electrical methods and apparatus. He is also indebted to Messrs. Barwell, Mackenzie Davidson, Lynn Thomas, Professor Waymouth Reid, and many others, for the use of Röntgen photographs and of notes of cases. Where all is new, it is by no means easy to decide what is likely to prove ultimately true; but the task of selection has been guided by a constant reference to the everyday conditions of medical practice.

D. W.

September 1, 1897.

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THE RÖNTGEN RAYS IN MEDICAL WORK

PART I

THE ELECTRICAL APPARATUS

By H. LEWIS JONES, M.D.

CHAPTER I

INTRODUCTORY

Lenard and Röntgen—The work of Crookes—Kathode rays and electrons—Sources of current.

Kathode Rays and Electrons.—The discovery of the *x*-rays was made by Röntgen at the end of the year 1895. It followed upon the work of Lenard, who found, when experimenting with the highly-exhausted Crookes tubes, that certain effects could be observed outside the tube. Before that time attention had been fixed upon the phenomena within the tube, and outside effects had not been noticed. Lenard, in 1894, following up a hint given to him by Hertz, and working with tubes provided with an aluminium 'window,' found that such tubes emitted radiations which could be recognised in the open air outside the window, and that these radiations had the power of exciting phosphorescence and fluorescence * in suitable bodies, and of acting upon sensitive photographic plates. He gave the name of 'kathode rays' to the radiations which he had thus discovered. In the following year Röntgen showed that a

* The word 'fluorescence' is used to signify a phosphorescence which does not last for any appreciable time after the withdrawal of the exciting stimulus.

Crookes tube gave out other rays, to which he gave the name of '*x*-rays,' and that these were of a different character from Lenard's kathode rays, inasmuch as they easily penetrated considerable thicknesses of bodies opaque to light, and could be made to produce impressions on a photographic plate, whereby any inequalities of density in a given object could be registered in the form of a photograph. Their penetrating power was much greater than that of Lenard's kathode rays.

After this it was a natural step to take a photograph showing the bones of the hand, and from that moment the modern science of *x*-ray work in surgical and medical practice came into being. Röntgen further showed by the use of screens painted over with fluorescent materials that it was possible to produce visible images of bodies by means of *x*-rays without having recourse to the employment of photographic plates.

A Crookes tube is a vacuum tube in which the exhaustion of the air has been carried to an excessively high degree—viz., about one millionth of the atmospheric pressure. It is so named because Sir William Crookes first interpreted the phenomena to be observed in such an apparatus. It differs from an ordinary vacuum or Geissler tube in its appearance when electrically excited. At low degrees of exhaustion a tube of the latter kind appears filled with glowing gas during the passage through it of an electrical discharge, but the highly-exhausted tube shows no such glow. It exhibits instead a peculiar fluorescence of its walls, which is of a pale yellowish-green colour when the tube is made of soda glass, and is blue when lead glass is employed. The fluorescence is caused by a bombardment of the glass by streams of negatively-charged gaseous particles propelled with enormous velocity from the kathode.

These streams of negatively-charged particles constitute the kathode rays, which were shown by Lenard to be able to pass through thin layers of aluminium, and to exist in the air immediately outside the 'window' of his tubes. The effect of the high exhaustion in a Crookes tube is to diminish the quantity of residual gas in the tube to such a degree that the particles set in motion at the kathode are able to move in straight lines for a considerable distance, and to strike the glass wall of the tube without obstruction or retardation through collision with one another. Thus, the higher the vacuum the more freely can they travel when once set in motion, and the longer is their 'mean free path.' In tubes of low vacuum their

movement is obstructed and arrested before they can travel the required distance, and the luminosity of the gas in such tubes is the result of the energy imparted to it by the collisions and consequent arrest of the negative particles. It was shown by Crookes that when the vacuum in the tube is sufficiently high, the particles are propelled in straight lines from the surface or surfaces of the kathode, and continue to travel in straight lines until they strike an obstacle, such as the walls of the tube itself, or of any body intentionally enclosed in the interior of the tube so as to lie in the path of their movements.

The particles moving from the kathode or kathode stream are not fragments of the metallic kathode itself. although this view was advanced by certain continental observers. Before the year 1891, Crookes had shown that this was not the case, and he maintained that they were derived from the residual gas in the vacuum tube, but were in a peculiar 'ultra-gaseous' condition, and he described them as representing a 'fourth state of matter,' or 'matter in radiation.' He uses the following remarkable words: 'The molecules . . . at these high exhaustions under electric stress have become exalted into an ultra-gaseous state in which very decided properties, previously masked, come into play.' It has been shown quite recently that the particles concerned in the kathode stream are not atoms or molecules, but are in a much finer state of subdivision, probably having a mass of about one-thousandth part of the mass of an atom, and the word 'electron' is used to signify them. The kathode rays are therefore to be regarded as a stream of negatively-charged electrons moving with an enormous velocity, considered to be one-tenth of the speed of light. They are therefore not rays in the ordinary sense of the word. In virtue of their nature as electrically-charged and moving particles they are acted upon by a magnetic pole, and can be deflected from their course by its means. It has been proved that x-rays are not influenced by a magnet, and this is evidence that x-rays differ from kathode rays in not being composed of electrically-charged particles.

When the kathode rays strike any solid object this motion is arrested, and it is their sudden impact or arrest of motion which gives rise to the x-rays. The x-rays are true rays—that is to say, —they are radiations or disturbances in the ether—and they thus differ fundamentally from the stream of negatively-charged electrons which constitutes the kathode rays.

In some of the forms of tube devised by Crookes for showing his effects the kathode rays strike upon the glass wall of the vacuum tube, while in others they impinge upon bodies enclosed within it, and at the point where they strike they excite fluorescence in suitable bodies, and also produce heat and generate *x*-rays. In the earliest *x*-ray tubes the kathode stream was simply directed upon a part of the wall of the glass bulb, which thus served as the source, or point of origin, of the *x*-rays, but it was found that these tubes were apt to crack from the heat produced. They were also unsuitable for obtaining sharply-defined *x*-ray photographs, because the rays were emitted from large and irregular surfaces, and therefore did not cast sharp shadows. In modern tubes the kathode stream is directed upon a metallic target, suitably placed inside the tube, and the 'focus' of the resulting pictures is much improved by this device.

The radiations known as *x*-rays differ from those which constitute light, not only in the matter of wave-length, in respect of which they are very much shorter than the shortest waves of the visible spectrum, but also by being composed of an irregular series of solitary impulses, waves or fractions of waves, whereas light is made up of regular and complete undulations in the ether, following one another in an unbroken sequence.

X-rays possess the property, which also is characteristic of ultra-violet light, that they can discharge an electrified body, upon which they fall, by ionizing the surrounding air. With *x*-rays, however, discharge takes place equally well whether the body be positively or negatively electrified, whereas ultra-violet light can only discharge bodies which are negatively charged. X-rays also excite fluorescence in certain substances, especially in the platinocyanides of barium and potassium, in some uranium compounds and in calcium tungstate, and this property is made use of for the direct examination of objects by means of *x*-rays. They act upon gelatino-bromide photographic plates, producing the same action as that of light, and they penetrate bodies opaque to ordinary light. In a general way it may be said that bodies resist the passage of the *x*-rays in proportion to the atomic weights of their component elements; thus aluminium, with an atomic weight of twenty-seven, is more transparent than sulphur, whose atomic weight is thirty-two, while platinum and lead, with far greater atomic weights, are much more opaque to the *x*-rays.

Under different conditions of the vacuum tube different qualities of rays are emitted, some being more penetrating than others; and this is made use of in practical work for obtaining the exact degree of penetration best suited for different special operations.

Correctly speaking, an *x*-ray tube in action is emitting rays of several different qualities or penetrating powers, and the rays emitted can be filtered, as it were, by causing them to pass through a layer of some substance which is capable of absorbing the less penetrating rays, while allowing the more penetrating rays to pass.

Production of X-Rays.—The essential parts for the production of *x*-rays are two in number—a Crookes tube, suitably modified, which will be spoken of as an *x*-ray tube, and an electrical apparatus capable of supplying currents at the electromotive force necessary to excite the tube to action.

The instruments in use for obtaining the high electromotive forces needed to excite an *x*-ray tube are the induction coil, the statical machine, and the high-potential transformer. The Tesla coil has also been tried, but is not a very satisfactory means of exciting *x*-ray tubes. The induction coil is the most generally useful for the purpose, and most practical *x*-ray work is performed by means of coils.

The statical machine offers certain advantages, but it has the one great disadvantage of not being portable, except in the smaller sizes, and these have not yet shown themselves equal to the coil. It is therefore not suitable for cases requiring the transportation of the apparatus to the bedside.

The main advantage of the statical machine consists in its simplicity. Whereas a coil requires accumulators to drive it—and the recharging of these accumulators may be a matter of great difficulty in remote or country places—the statical machine is a self-contained electrical apparatus, capable of generating the necessary electromotive force by itself whenever its handle is turned. The discharge of a static machine also gives a steady radiation with *x*-ray tubes, which is less tiring to the eye in screen work than the flickering light given by the interrupted discharges of the induction coil. In fact, for screen work in the consulting-room, and for medical practitioners living in remote places, the statical machine is admirable. For photography it is slower than the induction coil, because the output of current of a static machine is much below that of a coil; but, on the other hand, it gives photographs of fine

quality, and wherever an apparatus is required which need not be transported to the bedside of the patient, the statical machine has much to recommend it.

The discharges of the statical machine are unidirectional, and this is the reason why the *x*-ray pictures which it gives are clear. When the induction coil is used as the source of current some loss of sharpness follows by reason of the effect of the impulses in the wrong direction, which form part of the ordinary induction-coil discharge, and excite an irregular production of *x*-rays in the tube.

The idea of using transformers worked directly from the alternating mains, and wound to give an electromotive force sufficient to work *x*-ray tubes, has attracted the attention of many experimenters. The current of a transformer is, of course, an alternating one, and this has been an obstacle to the application of the idea. In 1900 M. Villard invented an extremely ingenious rectifying device for correcting this difficulty. It consists of a vacuum tube in which one terminal is enclosed in a narrowly-constricted portion of the tube, while the other is suspended freely in a wide portion. A tube of this kind will transmit current freely when the helix is the kathode; but when the current is in the opposite direction it transmits little or none. One or more of these valve tubes is arranged in series with the *x*-ray tube so as to arrest the impulses tending to traverse the *x*-ray tube in the wrong direction, while providing a free passage for the impulses in the other or correct direction. The valve tube is used in conjunction with an oil-immersed transformer, which raises the electromotive force to 60,000 volts.

This method has recently been developed by Messrs. Gaiffe and Co., of Paris, who have modified the above-mentioned disposition of the valve tubes, and place them in shunt to the *x*-ray tube, and they now manufacture a complete outfit for the excitation of *x*-ray tubes from the alternate current mains by the aid of a transformer. It will be described in Chapter VI.

Another method which enables *x*-ray tubes to be operated from a high-potential transformer consists of a revolving commutator driven by a synchronizing motor. Neither of these instruments has yet come into extended use, but it is quite possible that they may do so, as they offer certain advantages for the production of *x*-rays, particularly in places supplied by alternating current mains. A current which is strictly unidirectional has decided advantages in

the abolition of impulses in the wrong direction which tend to blur the photographic images and injure the tubes. With large induction coils, especially when they are worked from sources of current at high pressures, as from electric lighting circuits, these inverse impulses acquire an importance which is not nearly so evident when induction coils are driven from a battery of a few accumulator cells.

The Tesla coil affords a means of obtaining currents of high potential from the alternating electric light mains, and has been employed for *x*-ray work, but it is not very suitable for the purpose. Its discharges are oscillatory discharges of high frequency, and oscillatory discharges behave in a very peculiar manner inside a vacuum tube. Strange to say, it is very difficult to confine them to the leading-in wire, so as to deliver them where wanted at the surface of the kathode. They have a strong tendency to escape into the vacuum tube from the stem or support of the electrodes, in order to pass from the metallic conductor into the gaseous one. They are apt to puncture the glass sleeve or sheath surrounding the leading-in wires, and the bombardment at the punctured point heats the corresponding part of the wall of the tube, and causes it to puncture or crack. The waves of current in the wrong direction are also injurious to the tubes. For these reasons the use of the Tesla coil is now almost totally neglected in *x*-ray work.

CHAPTER II

THE X-RAY TUBE

Geissler tubes—Jackson's *x*-ray tube—Modern tubes—Regulation of vacuum —Measurement of current.

Vacuum Tubes.—Soon after the invention of the induction coil, it was found that a spark which passed with difficulty in air did so much more readily in a partial vacuum. An exhausted glass tube, having a piece of platinum wire sealed into its cavity at each end, becomes filled with a luminous glow when an electrical discharge is passed through it.

An apparatus of this kind is named a Geissler tube, and such tubes have been made in infinite variety of form on account of the beauty of the luminous effects produced with them. The gas at low pressure in these tubes conducts better than air at the ordinary atmospheric pressure, and a tube 12 or 18 inches long can be well lighted up throughout by a coil whose sparking distance in air is less than 1 inch. The various appearances of discharges through vacuum tubes, and the effects to be observed as the exhaustion of the air is carried further and further, have been described by many writers.

Beyond a certain degree of exhaustion the resistance of the tube increases gradually, and the luminous appearances inside the tube become fainter, until at last they disappear, to be replaced by a brilliant phosphorescence of the glass wall of the tube, which otherwise appears dark and empty.

The vacuum is then at a degree suitable for illustrating Crookes' experiments, and is commonly spoken of as a Crookes tube.

An account of the researches of Professor (now Sir William) Crookes on the phenomena in high vacua formed the subject of his presidential address to the Institution of Electrical Engineers in

1891, and his paper, illustrated with numerous figures of vacuum tubes in action at different degrees of exhaustion, will be found in the *Journal of the Institution of Electrical Engineers* for 1891, and in the *Electrician* for January, 1891.

A summary of the phenomena seen in vacuum tubes at different degrees of exhaustion has also been given by Sir Oliver Lodge in a recent address to the Institution of Electrical Engineers * on the subject of Electrons, and the student should also consult 'The Discharge of Electricity through Gases,'† by J. J. Thomson, for much valuable information, simply stated, on the subject of kathode rays and allied phenomena.

X-Ray Tubes.—A Crookes tube in action emits *x*-rays, as was shown by Röntgen, and a most important step in the application of Röntgen's discovery was the invention of a really good form of vacuum tube for practical use; and with this object numerous tubes have been designed in a great variety of shapes. We have already seen that in the earliest tubes the kathode was a flat disc, the bombardment from which was projected upon the opposite surface of the tube, which was pear-shaped, with an anode in the form of a ring, so as not to obstruct the kathode stream in its passage to the base of the bulb (Fig. 1); but the form now adopted in all tubes is that devised by Mr. Herbert Jackson, in which a metallic anode, 'anti-kathode,' or 'target,' is fixed within the tube so as to be near the focus or point of convergence of the bombardment from a concave kathode.

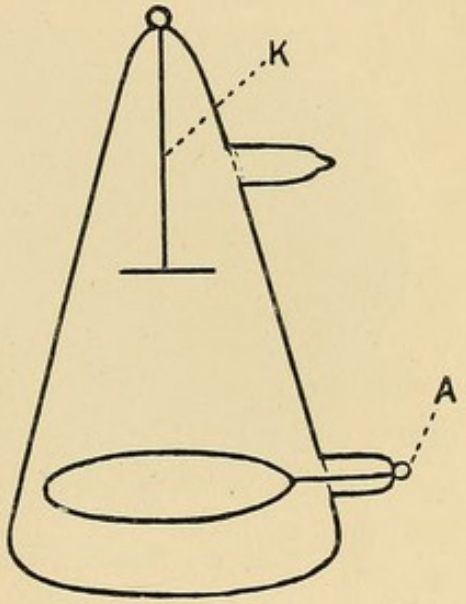


FIG. 1.—ORIGINAL PATTERN OF X-RAY TUBE.
A, Anode; K, kathode.

By this device he greatly improved the definition of *x*-ray photographs, the *x*-rays arising from a small area of the platinum target, and not, as in the older tubes, from a large area of the glass wall of the tube.

The platinum target, or anti-kathode, is fixed obliquely to the axis of the tube in order that the main part of the Röntgen rays may be

* *Journal of the Institution of Electrical Engineers*, November, 1902.
† Constable and Co., London, 1903.

directed to one side of the tube, and hence may be readily thrown upon the object to be investigated, and upon the fluorescent screen or the photographic plate. The original form of Jackson's 'focus' tube is shown in Fig. 2. The cup-shaped kathode is of aluminium, the target or anti-kathode of platinum, and both are in communication with the exterior of the tube by platinum wires sealed through the glass. The anti-kathode acts also as the anode of the system. The wire stems of both electrodes are provided with sleeves of glass tube, which tend to concentrate the discharges at their terminal surfaces.

In most forms of vacuum tube the kathode is made of aluminium, because this metal does not become disintegrated under the action of the discharges. Most metals, when they form the kathode in a

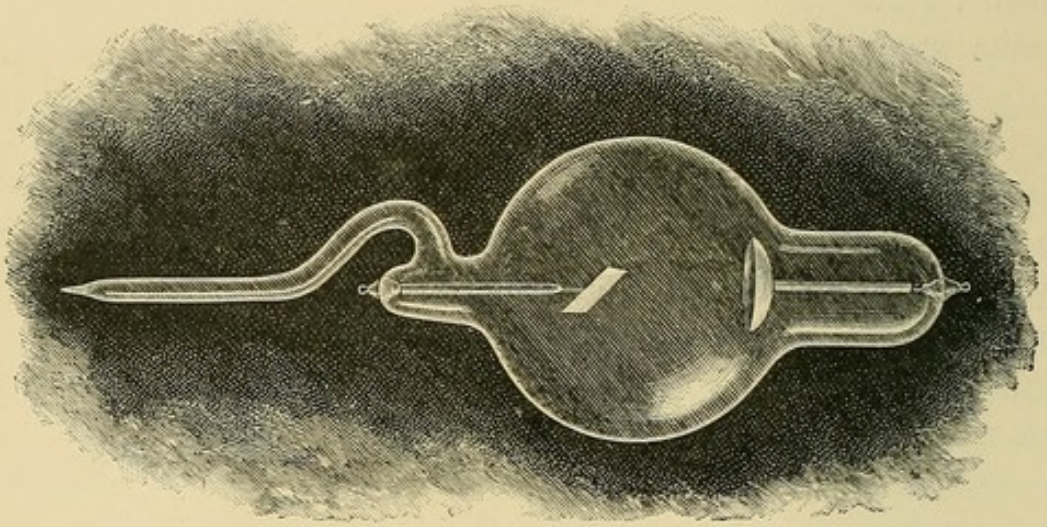


Fig. 2.—Focus Tube* (Original Model of Jackson).

vacuum tube, are thrown off in minute particles, and are deposited as a film upon the adjoining parts of the wall of the tube.

For the anti-kathode a dense and infusible metal is required, and platinum is very generally used. Osmium has been employed by Mr. Mackenzie Davidson, who found that platinum is too soft a metal to stand the full effects of a sustained bombardment concentrated upon one point on its surface. Generally, in *x*-ray tubes the platinum anti-kathode is intentionally placed at a little distance beyond the actual focus of the kathode, in order to enable it to withstand the disintegrating effects of the bombardment. When osmium is used, its hardness and infusibility make it possible to place it in the exact focus of the discharge, and therefore the *x*-rays emitted by such a tube come from a smaller radiant

* From Lewis Wright's 'Induction Coil.'

point, and throw sharper images than ordinary tubes. Unfortunately the osmium anti-kathodes have proved difficult to procure and troublesome to work with, and have not come into general use. Nickel is now commonly employed for anti-kathodes by many tube manufacturers.

The appearance of an *x*-ray tube in action is characteristic. It shows a hemisphere of bright green phosphorescence on that part of the glass which lies in front of the plane of the anti-kathode surface, while the tube behind this plane is almost free from any green colour. A faint bluish luminosity in the gas itself within the tube may be seen around the back of the anti-kathode if the vacuum is low, and this appearance of visible gas may be used as an indication of the quality of the tube, for the lower the vacuum the more evident is the luminosity of the gas. The amount of *x*-rays may be

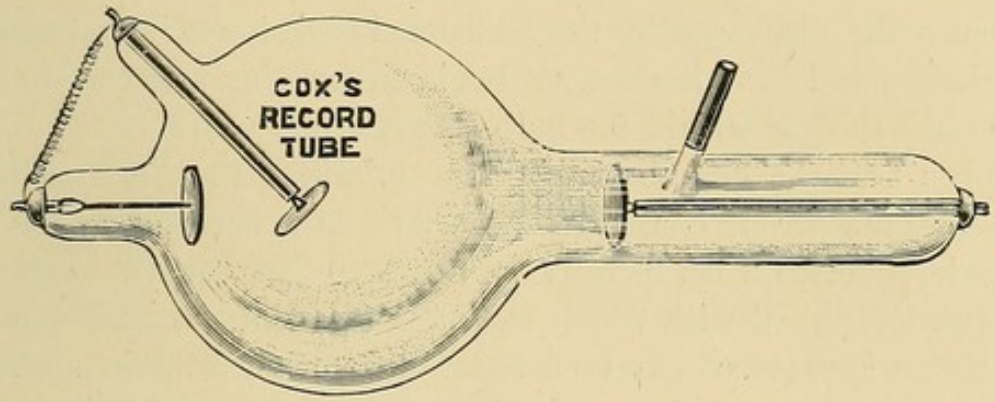


FIG. 3.—FOCUS TUBE, SHOWING ANTI-KATHODE, OR TARGET, AND EXTRA ANODE.

estimated from the brightness of the fluorescent hemisphere if the room is dark. In daylight the fluorescence is easily overpowered. Though fluorescence goes hand in hand with *x*-ray production, the glass may be appreciably green in tubes which are so low as to be almost useless for *x*-ray work, but in such cases the true state of affairs is easily recognised by the presence of much luminosity in the gaseous contents of the tube. If the current through the tube is in the wrong direction, the tube presents irregular patches of green appearance, and no hemisphere of fluorescence is recognisable.

Among the modifications of form which the focus tube has undergone, the chief has been the introduction of a third electrode (Fig. 3), which is connected by a wire to the anti-kathode, externally to the tube. This has come into universal use, and it is believed to act as a steadier of the tube. After long use the resistance of an *x*-ray

tube increases, until in time it may become too high for the coil for which it was originally fitted, and it is then useless unless a more powerful coil can be obtained. Tubes with a third electrode change in resistance more slowly than do those of the original pattern. The probable action of the third pole is to serve as a means of supplying positive charges to, or of carring off negative charges from, the atoms of residual gas.

Sir Oliver Lodge, in his lectures on 'Physics applied to Medicine,' describes the supplementary anode as serving to give an easier path to the slow-moving positive ions, which have to find their way to the kathode, and in that way to complete the circulation within the tube.

C. E. S. Phillips* believes that the auxiliary electrode has, as its greatest function, an electrostatic action serving to attract irregularly moving streams of electrified gas towards it, that it tends to influence the discharge by the additional capacity it introduces into the circuit, and that it does not begin to exert an appreciable influence until the gas within the bulb is exceedingly rare.

Tubes like the one shown in Fig. 6, which have an uncovered metallic cylinder of considerable surface as a backing to the anti-kathode, seem to work equally well, and to last equally long, when the third terminal with which they are fitted is not connected up, the larger amount of exposed metal which they contain appearing to exercise a function similar to that of the extra anode of the tubes of ordinary pattern.

The actual degree of vacuum which is best in a tube will depend upon the electromotive force used for exciting it. Thus, a tube which is too high for a small coil will serve admirably for another of greater size. There are, therefore, fairly wide limits of vacuum within which x-ray effects can be produced. The higher the vacuum in the tube, the greater is the electromotive force necessary to work it, but the greater is the power of penetration of the x-ray radiance emitted. At the high vacuum the velocity of the bombardment is greater by reason of the higher electromotive force applied to the tube, and the x-rays generated are more penetrative. Sir Oliver Lodge writes as follows of high-resistance tubes:† 'The rays given off are then specially penetrative: the reason is that the kathode rays come flying off without obstruction, reach a maximum speed,

* *Archives of the Röntgen Ray*, vol. vi., p. 48.

† *Ibid.*, 1904.

and are more suddenly stopped. The higher the vacuum, the thinner the pulse of the *x*-rays, and the more penetrating they are.'

The words 'soft' and 'hard' are commonly used to designate tubes of lower and of higher resistance respectively. Thus we may say that a tube which is 'soft' when new will gradually become harder and harder with use, and will therefore become more suitable for photographing the thicker parts of the body, and less uitable for photographing the thin ones. If too 'hard,' its rays may have too high a penetration, and will then traverse bones almost as freely as soft tissues, and will give a photograph in which the contrasts between the bones and the soft tissues are insufficiently marked.

Another respect in which there has been a gradual change in *x*-ray tubes is in their size. Their dimensions have increased progressively since their introduction. It is found that a large tube ages less rapidly than a small one, and varies less in its condition during the period of an *x*-ray application, and is also better able to withstand the heavy strains and hard work to which modern *x*-ray tubes are commonly subjected.

The increased resistance of an old tube is probably due to the absorption or 'occlusion' of some of its gaseous contents by the wall of the tube, by the electrodes, or by the finely disintegrated particles of the anti-kathode which are gradually thrown off, and which adhere to the glass of the tube. This ageing is especially promoted if the current is allowed to pass through the tube in the wrong direction; for, as has already been mentioned, most metals other than aluminium are disintegrated when they are acting as the kathode of a vacuum tube. Care should therefore be taken to preserve the correct direction of current whenever *x*-ray tubes are used. A tube that has been carefully used gradually acquires a violet tint in the hemisphere corresponding to its effective side, by reason of chemical changes in the substance of the glass; but a tube allowed to work improperly becomes blackened more or less all over, from a metallic deposit upon its inner surface.

Regulation of Vacuum.—The inconveniences arising from the gradual ageing of *x*-ray tubes when in use have led to the introduction of many contrivances for lowering the vacuum when it has become too high. An easy method of temporarily lowering a tube is to warm it all over with a spirit-lamp flame or before a fire. For warming the tube when it is in action, the operator should

employ a lamp with a long non-conducting handle to protect himself from shock and his hands from risk of *x*-ray burns. A tube whose resistance is lowered in this way becomes as hard as before as soon as it has cooled ; but prolonged warming of a tube—as, for instance by baking it in an oven at a high temperature for some hours—will often lower an *x*-ray tube more or less permanently. Another method of lowering the resistance of a tube which is too high depends upon the inclusion in a side-tube of a chemical compound which gives off vapour when warmed. When such a tube becomes too high its vacuum can be lowered by the warmth of a spirit-lamp applied cautiously to the part containing the chemical compound.

A simple method which may be used to lower the resistance of a

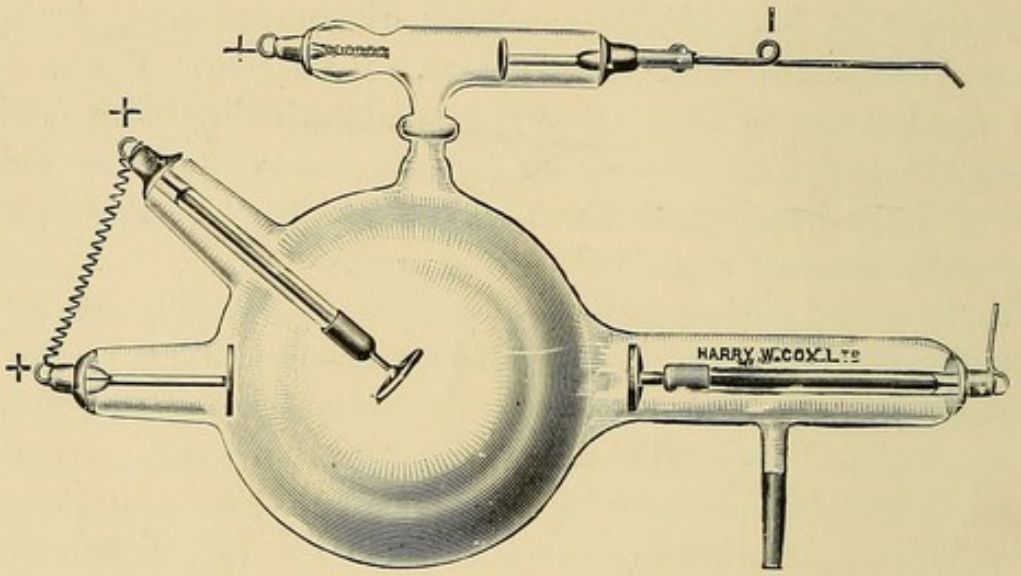


FIG. 4.—SELF-REGULATING TUBE (H. COX).

high tube is the following : A sheath of damp lint or cotton-wool is applied to the kathodal end of the tube. It should extend along the glass to a point level with the surface of the kathode, and should also touch the leading-in wire. It gives a negative charge to the outside of the glass, and probably promotes the movement of positive ions to the region round the kathode. The effect of this device upon the apparent resistance of the tube is very marked, and its use will often permit of the employment of a tube which otherwise would be too hard for use.

Most modern tubes are provided with regulating devices of a more permanent character. One of these methods of tube-regulation is the use of an accessory side-bulb to the tube, which is furnished with terminals between which sparks can be passed at

will. The special terminals of the side-tube are constructed of some material which will emit gas when heated by the passage of sparks, and the gas so disengaged enters the main body of the tube, and lowers the vacuum. One of the substances used for the purpose is mica in the form of discs fixed to the terminals of the side-tube. Fig. 4 shows a tube fitted with this form of regulating device The long wire projecting from the side-tube is hinged, and can be placed at such a distance from the kathode of the tube that a spark may pass to it whenever the vacuum becomes too high, and in this way the tube is made self-regulating. The terminals marked + may be permanently connected together. These

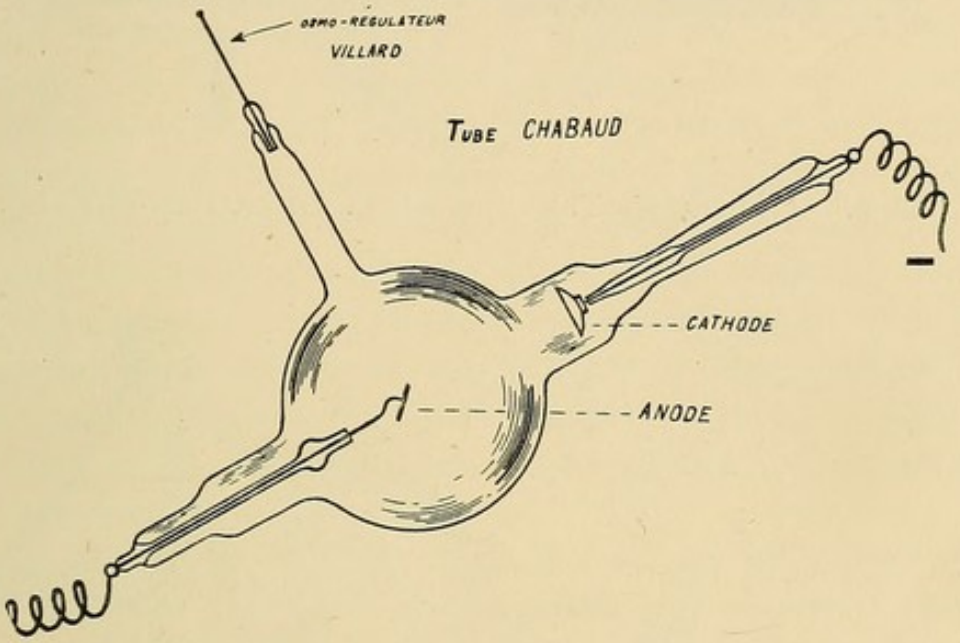


FIG. 5.—FRENCH FORM OF X-RAY TUBE (CHABAUD TUBE), SHOWING THE OSMO-REGULATOR OF VILLARD (MEDICAL SUPPLY ASSOCIATION).

tubes need care in management. When they are new, the effect of the passage of sparks through the side-tube is apt to be greater than is desired, and the vacuum in the tube may easily be reduced too much; and when old, the emission of gas from the side-tube when excited may become deficient.

A most ingenious method of reducing the vacuum is based upon the power possessed by platinum of becoming permeable to hydrogen when heated. A thin-walled tubular wire of platinum, closed at its outer end, is sealed into a side-branch of the *x*-ray tube. It projects outwardly for a distance of about 2 inches. If the outwardly projecting part is heated to redness in a spirit-lamp flame, hydrogen from the flame is absorbed by the metal, and passes

through it into the tube. This contrivance is known in France as the osmo-regulator of Villard. It is shown in Figs. 5, 6, and 7. The platinum tube is delicate, and should be protected by a glass cap, as shown in Figs. 6 and 7. With this device the resistance of a tube can be lowered as often as may be desired. With the other contrivances previously described this is not the case.*

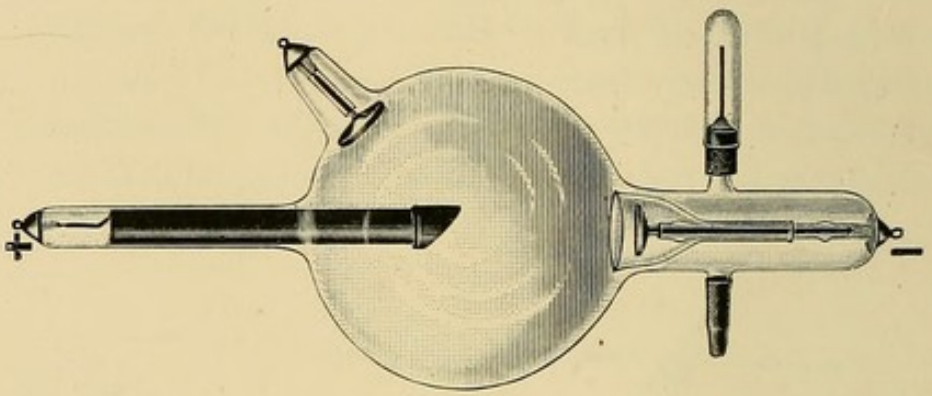


FIG. 6.—GUNDELACH'S TUBE FOR HEAVY DISCHARGES (SCHALL).

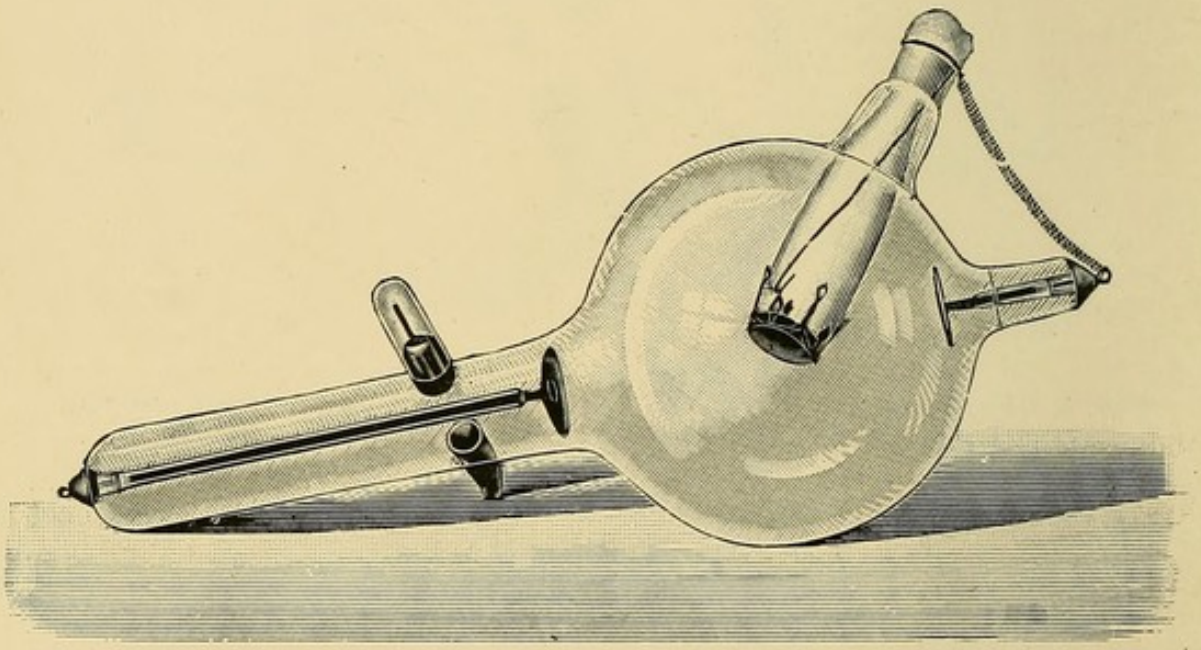


FIG. 7.—TUBE FOR HEAVY CURRENTS WITH WATER-COOLED ANTI-KATHODE (SANITAS COMPANY).

It is said that the osmo-regulator of Villard can be used to produce the opposite effect of increasing the vacuum within the

* The osmo-regulators fitted to tubes made in Germany, are of very thin metal, and admit gas with excessive readiness. A few seconds of heating is therefore all that they should receive at a time. The French regulators are more substantial and much better to work with.

tube, if this should be necessary. To effect this, the platinum tube is enclosed in a loose sleeve of platinum open at both ends. When this sleeve is held in the flame it is traversed by a flow of atmospheric air, and shields the red-hot inner tube from the gases of the flame. Under these conditions there is a tendency for hydrogen gas to diffuse outwards from the inside of the *x*-ray tube. This is a slower and less certain process than that previously described, and it acts only when hydrogen gas is present within the tube, as a result of previous operations for reducing the vacuum. The usual method of increasing the resistance of a tube which is too low is by running a gentle current through it in the wrong direction for a few minutes.

Comparison of Tubes.—The resistance of a tube is usually specified in terms of the length of air-gap which offers an equal resistance. If the points of the discharger of the coil be gradually brought near to one another while the coil is in action and supplying an *x*-ray tube, a distance is reached at which the current passes by preference through the air between the discharging points, instead of taking the path through the tube. With different tubes the sparking distance of the discharging points varies considerably, consequently this method of measuring the 'alternative path' provides a means of comparing the resistances of different tubes, and their resistances can be expressed by giving the length of the 'equivalent sparking distance.'

If the sliding rods of the discharger are suitably graduated in inches or centimetres, the measurement of the alternative path is made easier, and the contrivance has been called a spinter-meter, or spark-measurer.

The method just described enables one to compare the resistances of *x*-ray tubes, and so to form an idea as to the penetrating quality of the radiation they will emit, but it does not afford any information as to the amount of *x*-rays emitted. The two factors, quantity of radiation and quality of radiation, are quite distinct, and must not be confounded together.

Another way of estimating the quality of the *x*-rays, or their penetrating power, consists in a comparison of the relative opacities of two or more bodies of different densities, as shown by the rays under examination. This is done in a rough way when the image of the hand is viewed on the fluorescent screen, and the blackness of the shadow cast by the bones is compared with that shown by the soft parts. When the bones appear relatively dark, the rays

of the tube are said to have a low degree of penetration ; and when they cast a shadow which is hardly darker than the soft tissues, the tube is said to be giving rays of high penetration.

The radio-chromometer of L. Benoist is an instrument for observing and comparing the relative opacities of two dissimilar metals, silver and aluminium being chosen for the purpose. In this way the penetrating quality of the rays given out by a tube may be determined. Röntgen had previously designed a similar apparatus, in which aluminium was compared with platinum. Benoist's instrument consists of a disc of aluminium, so cut away in steps as to form a series of twelve sectors, from 1 to 12 millimetres in thickness, arranged in order around a centre. The aluminium of the centre of the disc is removed, and the opening is occupied by a circular piece of sheet silver, of a thickness of 0·11 of a millimetre. To test a tube, the shadow of the whole combination is viewed on a fluorescent screen, and the amount of fluorescent effect transmitted through the silver is compared by the eye with that coming through the different thicknesses of aluminium. Some of these appear brighter and some darker than the central silver disc, and the penetrating power of the rays is deduced by observing which of the numbered thicknesses of aluminium throws a shadow most closely comparable to that of the silver. With a tube of high penetration the shadow of the ninth or tenth thickness of aluminium is equal to that of the silver ; with a low tube, the thinner layers numbered two or three give the best match. A similar but more elaborate apparatus has been designed by Wehnelt, and is called a crypto-radiometer.

Röntgen has pointed out that the interposition of a substance such as glass between the tube and the scale has the effect of altering the ratios shown in this type of instrument, by its effect in stopping the rays of low penetration.

The chromo-radiometer of Holtzknecht is an instrument which serves to measure the quantity of rays emitted by a focus-tube in a given time, just in the manner in which a piece of sensitive paper is used to measure ordinary light for making photographic exposures. It consists of pastilles containing a chemical substance, the colour of which grows gradually darker under the influence of the rays ; a pastille of this material is exposed simultaneously with the patient, and the change in its colour is compared from time to time with a standard scale. The amount of effect can thus be estimated. The composition of the material used by Holtzknecht is not made public,

but it appears to be a mixture of sulphate of potash with celloidin. The colour changes from yellowish to dark green under the influence of *x*-rays, but the material is hardly sensitive enough for accurate determinations or for short exposures. The apparatus has fallen into disuse.

For the same purpose Sabouraud and Noiré recommend the use of small discs of paper, thickly coated with platinocyanide of barium. This substance changes colour when exposed to the rays, and, as the change of colour is proportional to the exposure, a comparison of the exposed disc, with a standard tint, enables one to estimate when a certain degree of exposure has been reached. The platino-cyanide disc is directed to be placed on a metallic support at a distance of 8 centimetres ($3\frac{1}{4}$ inches) from the anti-kathode of the tube—that is to say, it must be close to the wall of the tube. Holtzknecht's pastilles were affixed to the region of the patient which is exposed to the rays—an arrangement which presents obvious advantages.

A solution of iodoform in chloroform has also been proposed by Freund for measuring the quantity of *x*-rays. Here, too, there is a difficulty, for the solution is rather unstable unless both ingredients are of the highest purity, and ordinary daylight acts on it in the same way as *x*-rays, setting free iodine with the production of a pink colour.

Measurement of Current.—It has been found that the currents of the *x*-ray circuit may be passed through a galvanometer without breaking down the insulation of its windings. A galvanometer can therefore be used to measure the actual current in milliampères which is passed through the *x*-ray tube; and some experiments of D'Arsonval show that the photographic effect is proportionate to the actual current which is passing. This procedure is quite different from that of measuring the current in the primary circuit—a procedure which has had a certain vogue in the past, although useless as a guide to the output of the *x*-ray tube set in action thereby. D'Arsonval showed before the Academy of Sciences that photographs taken with different currents through *x*-ray tubes were identical when the times of exposure were so adjusted that the figures obtained by multiplying current by time were equal. For example, three exposures were made: one with 0·45 milliampère for 45 seconds, one with 1·0 milliampère and 20 seconds, and a third with 1·25 milliampères and 15·5 seconds. By multiplying the figures for the time and the current the numbers

in milliampère-seconds are as follows: for the first, 20·25; for the second, 20·00; and for the third, 20·47. The photographs exhibited were identical.

It appears highly probable that in the future a milliampèremeter will be used in the circuit of the *x*-ray tube in order to measure the production of *x* rays. The resistance of the tube, or its 'hardness,' can be simultaneously determined by the alternative spark method or by Benoist's instrument; and thus, by specifying the current in milliampères and the time of the application in seconds or minutes, these numbers, coupled with a measurement of the distance from the tube to the plate, will provide all the necessary data for an exact estimation of the conditions of an exposure.

Several forms of milliampèremeter are now made for *x*-ray work. The instrument shown in Fig. 8 is one which measures the total current that passes through the tube in both directions. It is arranged for attachment to the tube-stand, or it can be fixed to a wall or table. With a smoothly-acting mercury break the needle keeps quite steady, but with a platinum hammer interrupter some swinging is unavoidable. This instrument measures both components of the alternating current of the coil.

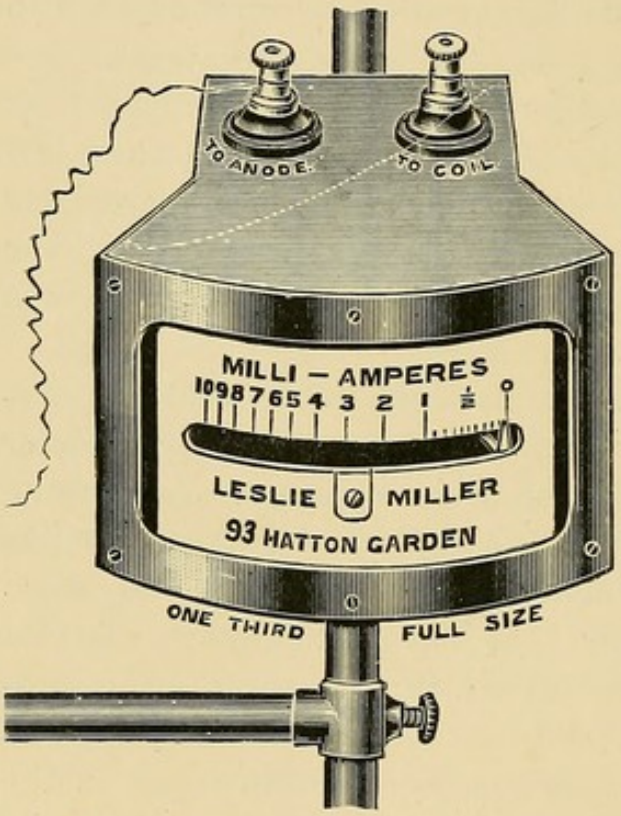


FIG. 8.—MILLIAMPÈREMETER FOR X-RAY WORK (L. MILLER).

In order to measure the effective current through an *x*-ray tube with any real accuracy, it is desirable that current in the wrong direction should be eliminated as far as possible. This is necessary not so much because of any difficulty in the measurement of currents which alternate in direction, but because it would be a misleading operation to measure currents of which some unknown proportion was ineffective in the production of the *x*-rays.

The Valve Tube of Villard.—In the case of the static machine the current is unidirectional, and can be measured easily by a

direct current galvanometer, but in working with an induction coil the inverse current may be a serious source of errors in measurement, particularly if the coil is operated from a source of supply at a high pressure—as, for instance, from the electric lighting mains, in which case the inverse current acquires considerable importance. A rectification of the current through the tube can be obtained by the valve tube of Villard, which has already been referred to. This apparatus (Fig. 9) is a vacuum tube of a moderate degree of exhaustion, made with a wide central space, into which one terminal projects freely in the form of a corkscrew of thick aluminium wire, while the other terminal is a straight rod of the same material, enclosed in a much narrowed part of the tube. Under these conditions the tube conducts easily when the first terminal is kathode, but has an extremely high resistance for currents in the other direction.

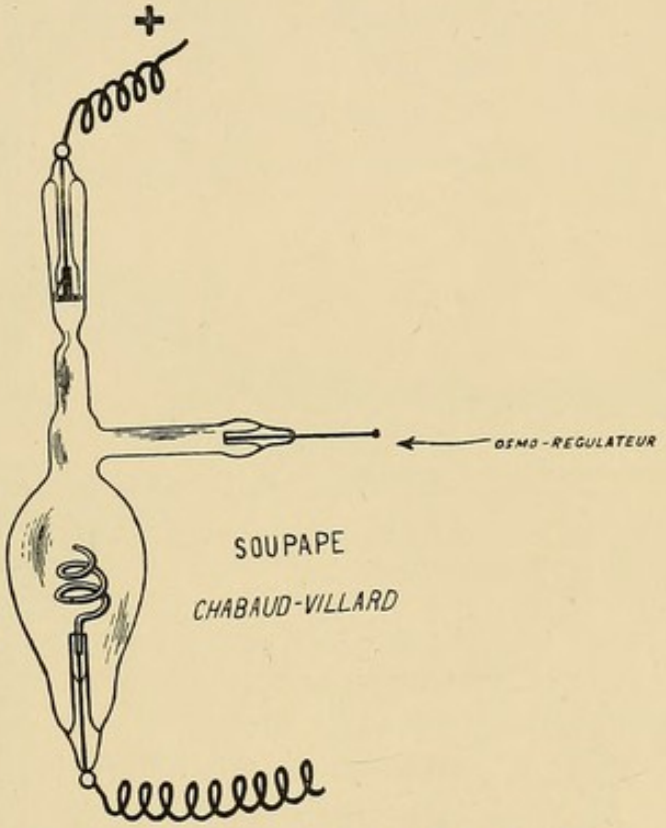


FIG. 9.—VALVE TUBE OF VILLARD WITH OSMO-REGULATOR (MEDICAL SUPPLY ASSOCIATION).

If one of these tubes is arranged in circuit with an *x*-ray tube, in such a way that the kathode, or large armature, is directly connected to the anode of the *x*-ray tube, it will offer a great obstacle to the passage of impulses through the latter in the wrong direction, and will notably improve the working of the tube, and will permit measurement of current to be made by means of a direct current milliampèremeter with a close approach to accuracy.

An ordinary medical milliampèremeter of the D'Arsonval pattern serves very well for use in the tube circuit. Slight modifications in the insulation of these instruments are now being made in order to protect their windings more fully from the risk of injury by sparks passing between their windings. Messrs. Gaiffe make a special

milliampèremeter, which will be seen represented in Fig. 49. Mr. Schall supplies a very convenient instrument which can be attached to the support of the tube-stand (Fig. 10), and is graduated in

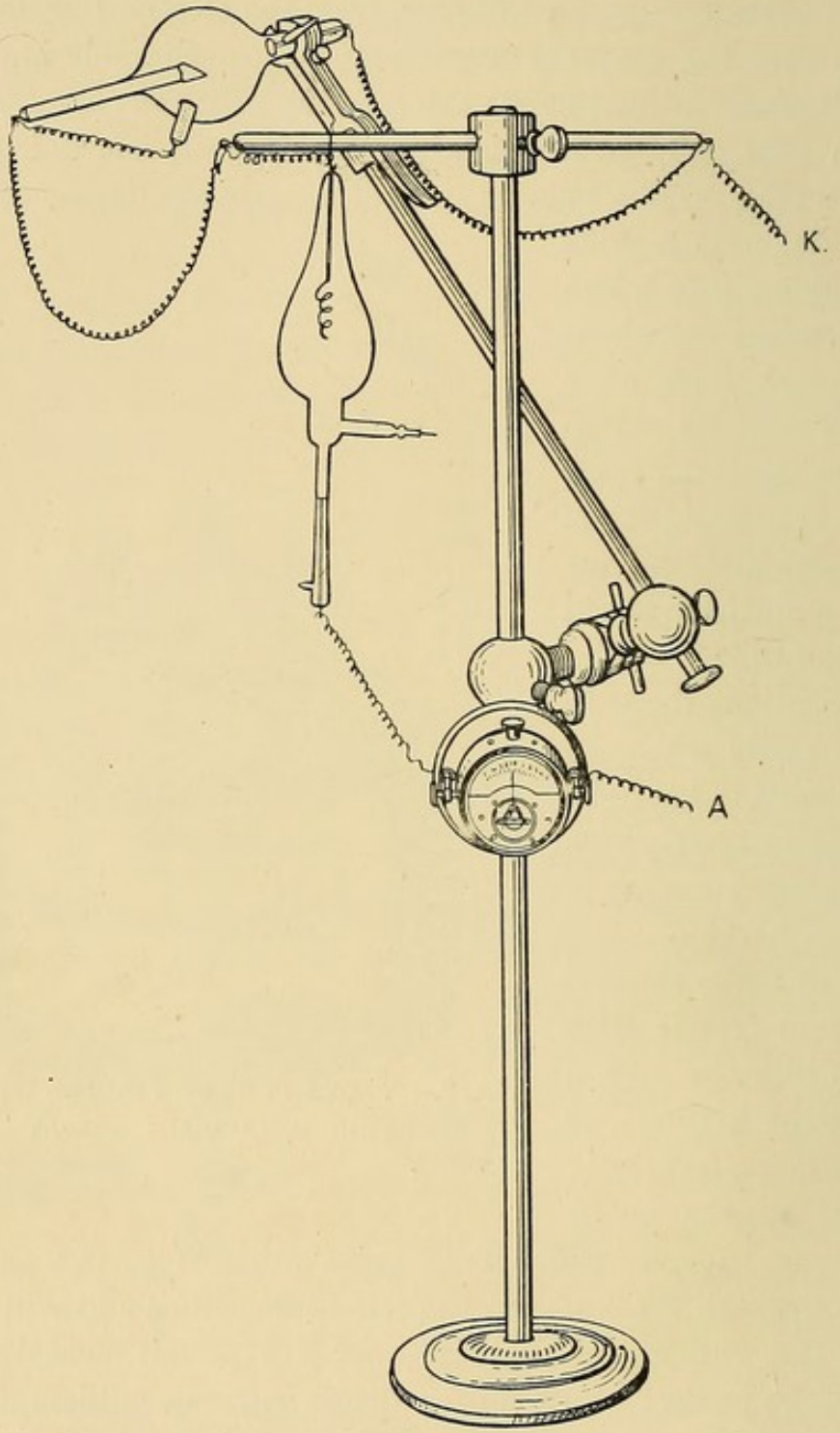


FIG. 10.—ARRANGEMENT OF GALVANOMETER AND VALVE TUBE IN THE X-RAY CIRCUIT.
A, K, Wires to anode and kathode of the coil.

tenths to 3 milliampères. This is the most generally convenient milliampèremeter in commerce at the present time.

The valve tube acts best when its vacuum is at such a stage as

to show a violet luminosity and no green fluorescence, and it should accordingly be provided with an osmo-regulator, or some other contrivance, for reducing its resistance when this has become too high through use.

The current through an *x*-ray tube ranges between 0·2 of a milliampère for hard tubes, and 1·0 milliampère for soft tubes. With larger currents than these the tubes quickly become over-heated. A current between 0·5 and 1·0 milliampère is sufficient for good average work.

When a direct current galvanometer is connected up in the circuit of an *x*-ray tube without the use of a valve-tube deflections will generally be obtained, and these represent the difference between the currents which are passing in the two opposing direc-

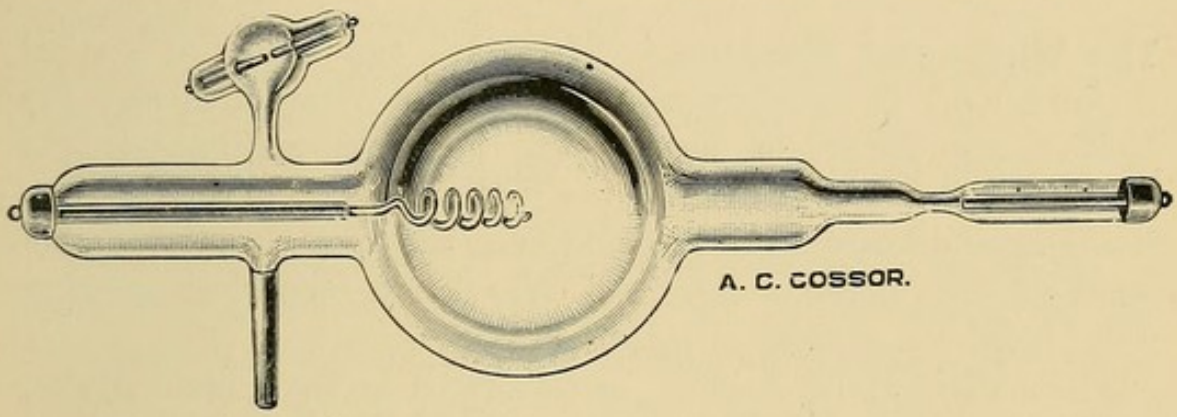


FIG. 11.—ANOTHER FORM OF VALVE TUBE (COSSOR).

tions. Sometimes, especially with low tubes, the deflection indicates that the inverse current is the greater; in other tubes the deflection indicates a predominance of current in the right direction.' In any case, the insertion of a valve tube alters the readings from those obtained without it in such a way as to show that its effect in stopping the inverse impulses is important for purposes of accurate measurement. In experimenting with three tubes, both with and without a valve tube in the circuit, the following readings (milliampères) were obtained:

	Tube No. 1.	Tube No. 2.	Tube No. 3.
A. Without valve	0·9	0·25	0·1
B. With valve	1·0	0·4	0·3

All these were selected tubes which gave fair deflections in the right direction without a valve tube. Tubes may easily be found in which the wrong direction of current predominates, but with the use of a valve tube this changes into a flow in the right direction.

CHAPTER III

STATIC MACHINES

The Holtz machine—Wimshurst's machine—Gaiffe's model—Enclosed machines.

The Wimshurst Machine. — There are two types of statical machine used for *x*-ray work—namely, the Wimshurst and the Holtz. The latter—or its variety, the Voss machine—is the favourite instrument in America, but it is rarely seen in this country. It is a more delicate apparatus, and more sensitive to unfavourable atmospheric conditions than the Wimshurst, but when working well furnishes a greater output of electricity.

The modern Holtz machine, as elaborated in the United States, is considerably modified from the original types devised by Holtz himself. It is a more trustworthy instrument, for it has no tendency to lose its excitation when running, nor to reverse its polarity.

In machines of the Holtz type all the moving plates rotate in one direction, and between them there are fixed inductor plates of glass. The excitation of the machine must be derived from an outside source in the first place, but once excited, the apparatus will continue to produce an abundant supply of electricity so long as the rotation of the plates is continued, particularly if the knobs of the discharges are so placed as to permit of a free discharge between them. Usually in Holtz machines a small accessory exciting machine of the Voss or Wimshurst type is fitted in a corner of the case.

In the Wimshurst machine, on the other hand, the plates are in pairs, and revolve in opposite directions to each other. Another difference between the Holtz and the Wimshurst machines, which is a consequence of their different plan of design, is that the former works

best when discharging freely, and the latter when not discharging freely. The Holtz, therefore, is less unfavourably affected by the small leakages and brush-discharges from the conductors which cannot be avoided in *x*-ray work; but, on the other hand, it is more likely to fail altogether in hot, damp weather. The form of machine known as the Voss machine resembles the Holtz in having fixed inductor plates, and possesses good self-exciting qualities.

The Wimshurst machine, in its simplest form, consists of a pair of glass or ebonite discs or plates, mounted upon a fixed horizontal spindle, in such a way that they can be made to rotate in opposite directions. The plates are fitted with pulleys, and are driven by belts from a counter-shaft, which is revolved by a winch-handle or by a motor, the opposite direction of rotation of one disc being obtained by crossing one of the belts. The discs are well varnished with shellac, and around the outer surfaces of the discs radial sector-shaped plates of tinfoil are disposed at equal angular distances. These sectors are not essential to the action of the machine, but they make it more easily self-exciting.

During the revolution of a plate the sectors forming a pair at opposite ends of a diameter of each disc are successively brought into metallic connection with one another by making simultaneous contact with a pair of fixed wire brushes, called the 'neutralizing brushes,' the sectors just grazing the tips of the brushes as they pass them. There is a pair of neutralizing brushes for each plate.

The position of the neutralizing brushes with respect to the fixed collecting combs and to one another is variable through a certain angle; but the best position seems to be one with the brushes touching the discs on diameters situated about 75 degrees from the collecting combs from which the sectors are moving.

The electricity generated by the rotation of the plates is collected by two fixed conductors furnished with combs or knife-edges, the usual position of the conductors, which are supported on glass or ebonite pillars, being along the horizontal diameter of the disc. To these fixed conductors are attached the terminal electrodes, or dischargers, whose distance apart can be varied.

The machine is self-exciting, provided there are sufficient sectors. In case of difficulty the neutralizing brushes must be seen to. If these are rightly placed, and making proper contacts, the machine cannot fail to excite.

Ebonite may be used for the plates instead of glass. It has the

advantage of being less liable to breakage, and ebonite plates can be safely driven at a high speed. There is, however, an objection to the use of ebonite, for it gradually deteriorates on the surface and loses its insulating properties, though it is admirable when new. Moreover, plates of ebonite are apt to give trouble through warping; glass is therefore the better material.

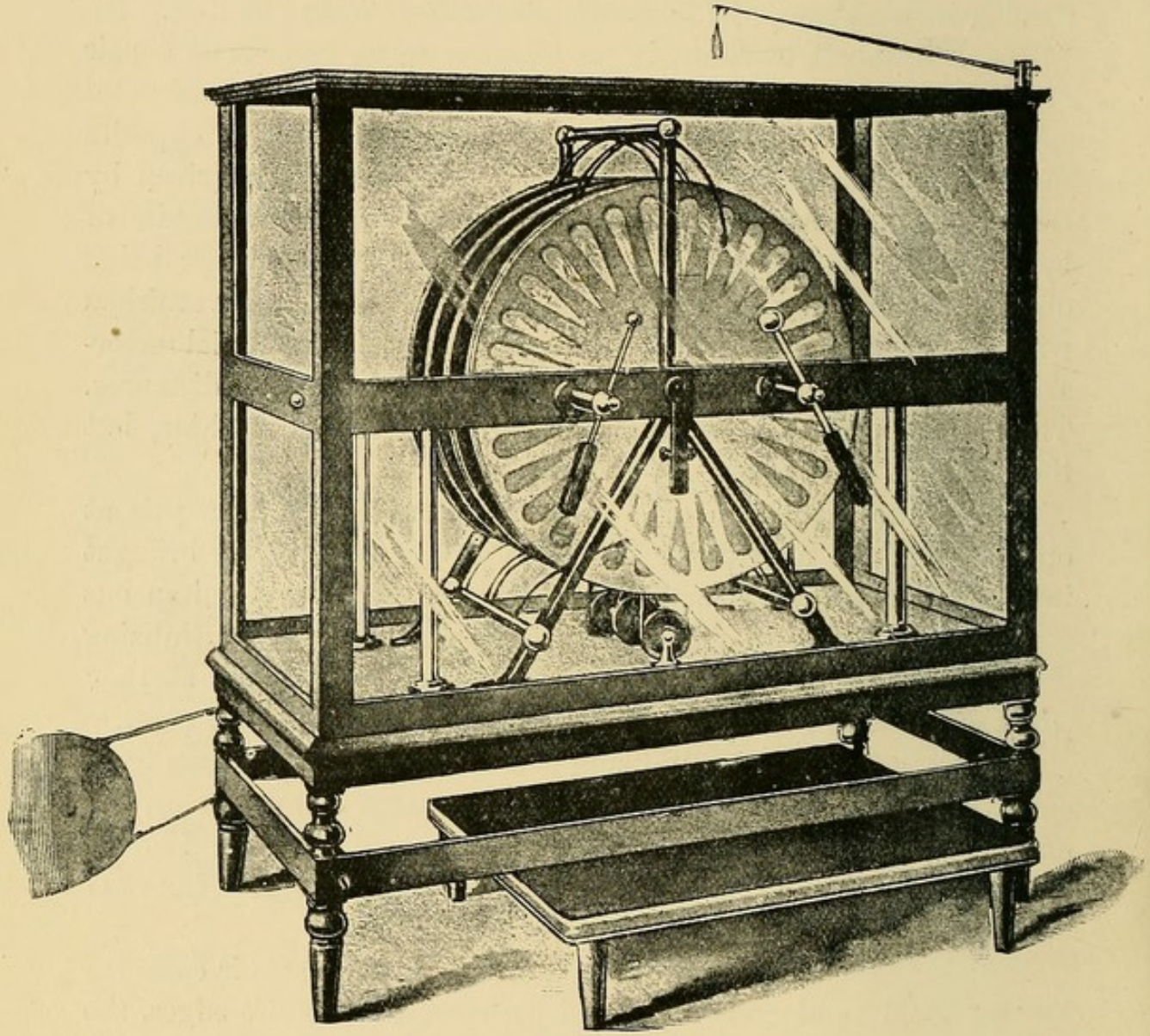


FIG. 12.—WIMSHURST MACHINE FOR X-RAY WORK (WATSON AND SON

Mr. Pidgeon has modified the construction of the Wimshurst machine by the addition of fixed inductors, and by carefully insulating the sectors, so as to reduce the leakage between one sector and another; and in this way he secures a larger output from a machine of a given size as compared with the output of an unmodified machine of the same dimensions.

It is advised that a Wimshurst machine for *x*-ray work should

have several pairs of plates. At least four plates of 36 inches diameter, or eight of 30 inches, are recommended. Small machines will serve to give images of the bones of the hand, but are inadequate for serious practical work. Fig. 12 shows a form of machine constructed by Messrs. Watson and Sons.

This machine gives streams of sparks of 10 or 12 inches even

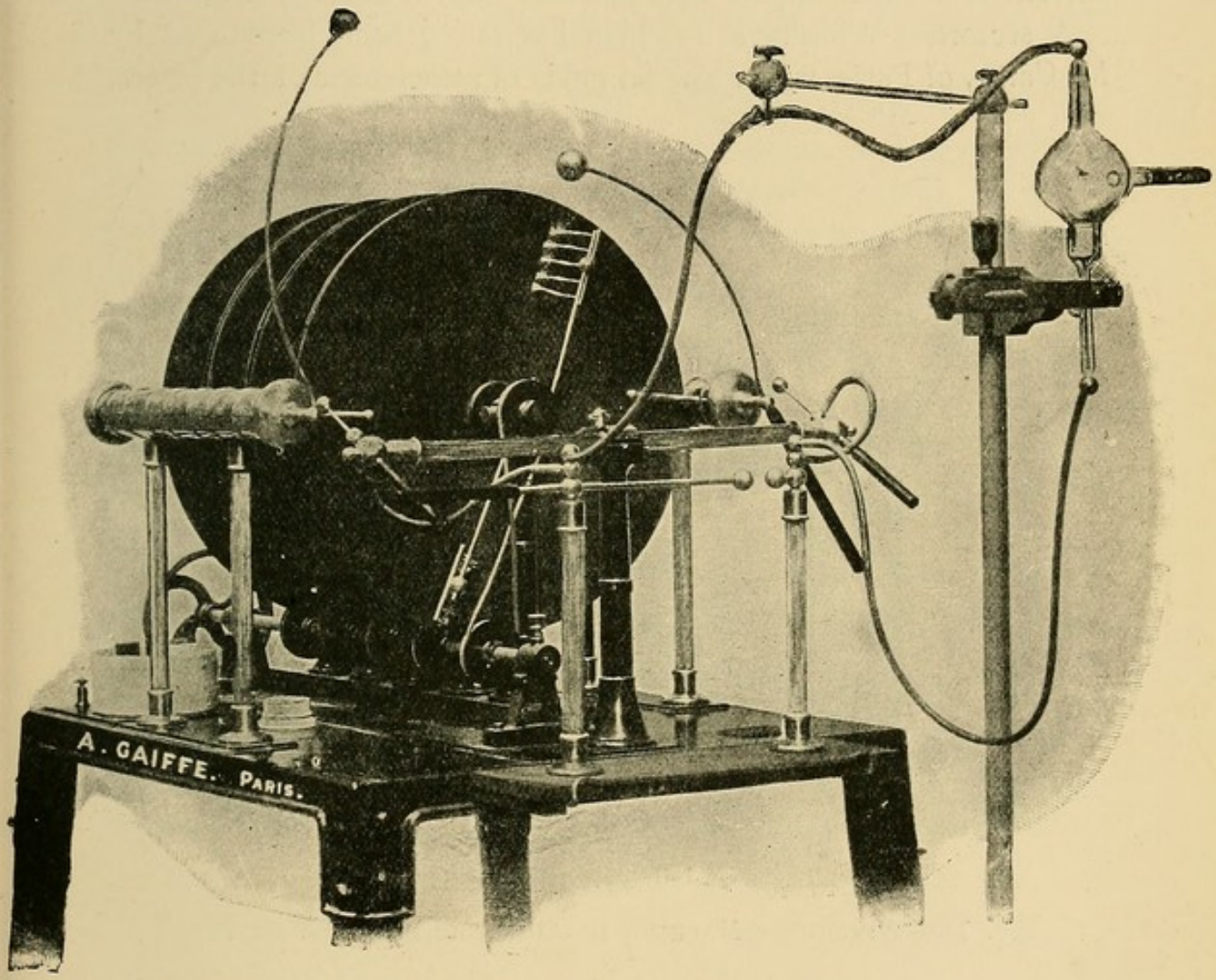


FIG. 13.—GAIFFE'S EIGHT-PLATE STATIC MACHINE (MEDICAL SUPPLY ASSOCIATION).

when running at the slow speed of one hundred revolutions a minute. It serves admirably for *x*-ray work with the fluorescent screen, and gives fine definition in photographs. The plates have thirty sectors. The stand is of steel tubing; the hubs are gun-metal. It runs silently and smoothly, and in my own hands has not failed to excite on any occasion during six years of regular use. A good case is an essential part of any static machine which is likely to be called upon for work at short notice.

A hinged clamp shown in the figure between the discharging terminals of the machine serves to hold an *x*-ray tube, and enables the knobs of the machine to be brought directly to the terminals of the tube without the intervention of wire conductors. This is useful in many applications to screen-work, and it reduces the losses from leakage by brush-discharges to a minimum. The machine gives a current of 0·2 milliampère with an *x*-ray tube of average hardness.

A sectorless Wimshurst machine has lately been introduced by M. Gaiffe, of Paris, with a special mode of attachment of the plates,

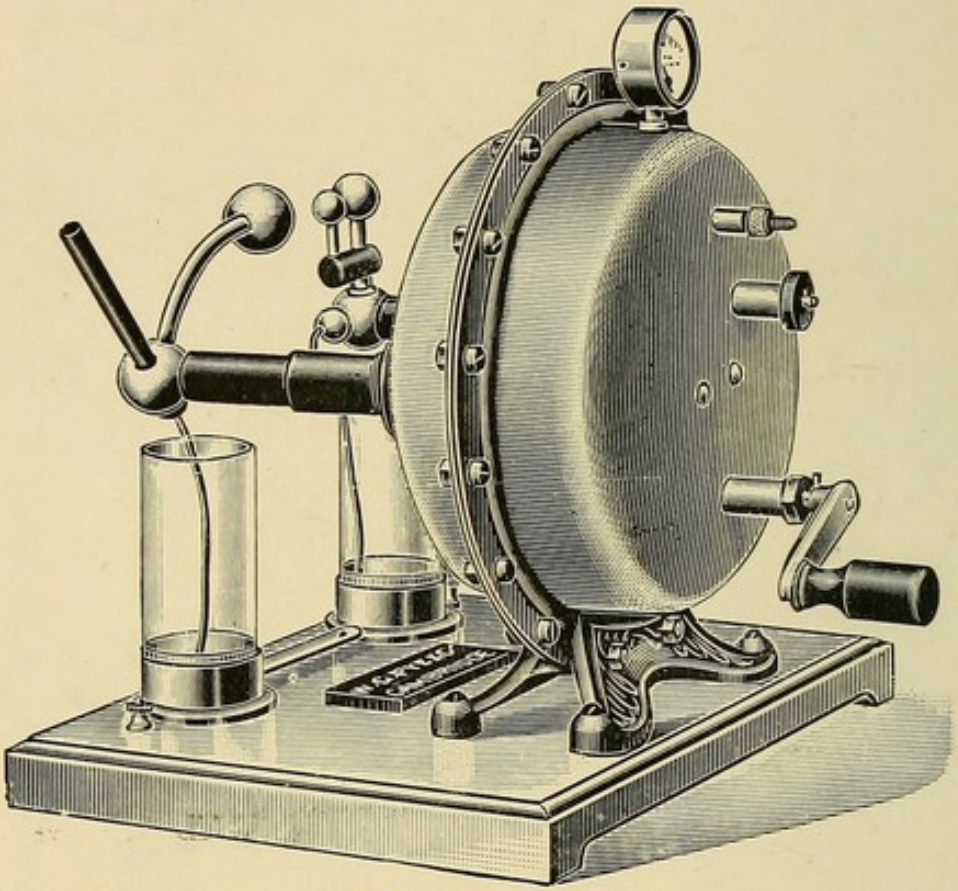


Fig. 14.—Wimshurst Machine in Air-tight Case (W. G. Pye).

which makes it easy to remove them for cleaning. He proposes by this means to do away with the need for a case, and so to lessen the cost of the apparatus.

The plates are of stout ebonite, 22 inches in diameter, and they can be run safely at the high speed of 1,000 revolutions per minute.

There are no sectors, and external excitation is usually required to start it into action, but when once started the output is large, and it gives good effects with *x*-ray tubes.

It is probable that the labour of keeping such a machine clean

would more than counterbalance the supposed advantages of saving the cost of a case. In the smoky air of towns the electro-static attraction of a machine in action will attract enough soot on a foggy day to blacken the plates in less than half an hour.

It has been proposed to enclose the Wimshurst machine in a strong metal case, and to work it under an air-pressure of several atmospheres, in order to reduce the internal leakage by brush discharges, which is one of the chief causes of the inefficiency of static machines.

Hitherto this idea has not been fully realized, but it is possible that an arrangement of this kind may in time be made successfully. Fig. 14 shows a machine of this kind, designed by Mr. F. Tudsbury, and made by W. G. Pye and Co.* The case is made of steel, and can be filled with compressed air by means of a bicycle-pump. Carbonic acid gas may also be used instead of atmospheric air, and a supply can be kept in readiness in a steel gas-bottle. The advantage of this gas over ordinary compressed air consists in the fact that it does not yield ozone under the influence of brush discharges, and the destructive effect of ozone upon ebonite can thus be avoided.

At present this machine is only made in small sizes, the stock pattern having plates of 6 inches in diameter, but even this small instrument is said to give sparks 5 inches long, when the internal air-pressure stands at 40 pounds per square inch. A larger machine to give 10-inch sparks can be made to order. If this type of machine were built on a larger scale, it might prove of substantial utility for *x*-ray work.

* Granta Works, Cambridge.

CHAPTER IV

INDUCTION COILS

The Ruhmkorff coil—Jointless section winding—Interrupters—Mackenzie Davidson's break—The turbine break—Electrolytic breaks.

The Ruhmkorff Coil.—Most *x*-ray work is done with induction coils which are capable of giving a 10- or 12-inch spark, and the coil is driven either by means of current from the electric lighting mains or by a battery of accumulator cells, eight, ten, or twelve of these being commonly used. The accumulator-driven coil may be regarded as the typical apparatus for *x*-ray work, and it will long continue to hold that position ; for it gives satisfactory results, it admits of use at the bedside or in military service in the field, and it is not directly dependent upon the presence of an electric lighting main.

Although many of the improvements which have been introduced into modern *x*-ray practice are due to the existence of electric light mains, they have the drawback that, while they improve the quality or the rapidity of the work which can be done, they nevertheless render the apparatus less easy of transportation, for they can be used only in places where electric light mains can be tapped, and they therefore lack the universality of application which is possessed by an equipment composed simply of coil and battery. Still, for permanent installations and for work of the highest quality, the introduction of methods permitting of the direct application of the electric light mains represents a most important advance and a great convenience.

The Ruhmkorff coil is an instrument for obtaining electrical discharges of high potential by a process of transformation from low-pressure currents.

Energy is not in any way created in an induction coil, and, owing

to various losses, the output of the apparatus is less than the energy which is supplied to it; therefore the great increase in the electromotive force of the discharges of a coil is accompanied by a corresponding decrease in the magnitude of the current compared with that supplied to the apparatus.

An induction coil consists of an iron core, on which are wound two independent circuits of wire. These are called the primary and secondary coils. The former conveys the exciting current, which magnetizes the core, and sets up a strong magnetic field through and around the secondary coil. The current in the primary coil is caused to vary rapidly by means of a mechanical device or interrupter, and rapid changes in the intensity of the magnetic field are thus produced, and react upon the windings of the secondary coil,

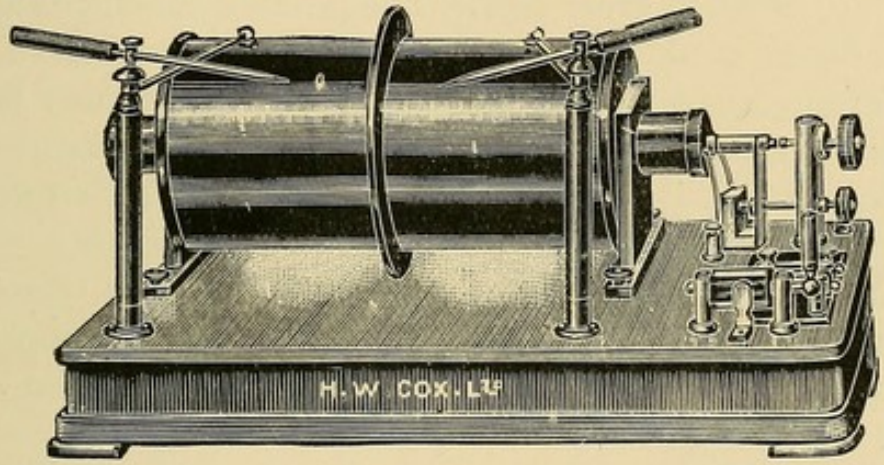


FIG. 15.—ORDINARY INDUCTION COIL, WITH HAMMER INTERRUPTER.

and induce an electromotive force in each turn of the wire. The sum of the electromotive forces in all the individual windings is the electromotive force of the whole coil. A condenser is also used in conjunction with the interrupter, as it has been found to be of great utility with most forms of interrupter.

The setting up of the magnetic field, when the current is 'turned on' in the primary, is a slower process than the collapse of the magnetic field when the current is broken, and the *rate of change* of the magnetic field being a factor of prime importance, the electromotive force induced in the secondary coil at the 'break' is by far the greater. This is fortunate, because when the current at 'break' is right for the excitation of the tube, the 'make' current is in the wrong direction.

The primary winding of a large coil is of thick copper wire, for it

has to carry currents of considerable magnitude without becoming heated. The core is made of a large bundle of fine iron wires, which have been carefully annealed to facilitate the magnetic changes which are to take place in them. The secondary coil is of fine wire, carefully covered with silk insulation, and ten miles or more may be required.

Ruhmkorff coils are commonly classified in terms of the length of spark which they are capable of giving. Thus, a 10-inch coil is one which can give a spark 10 inches long. For *x*-ray work, 10-, 12-, and even 18-inch coils are now in general use, although they are generally worked below their full power. The 12-inch coil may be regarded as the standard size.

These large coils require to be manufactured with care, and with attention to detail in every part. The primary windings are of two or three layers of thick copper wire, and in modern coils a plug or switch arrangement is used for connecting the primary layers in shunt or in series as may be required to suit the pressure of the supply from which it is driven, and the speed of the interrupter to be used with the coil.

For the proper designing of a primary coil two or three factors must be taken into account—viz., the voltage of the supply, and the frequency and duration of the interruptions of the contact-breaker.

For *x*-ray work no application requires a greater number of breaks per second than suffices to give steady illumination on an *x*-ray screen.

With the different forms of contact-breaking devices the number of interruptions in a given time is an increasing one in the following order:

1. The platinum or hammer break.
2. The mercury 'dipper' break with a straight plunge and reciprocal motion.
3. The mercury dipper break of the Mackenzie Davidson type, with a circular motion of the dipper.
4. The turbine break.
5. The electrolytic break.

And the number of turns in the primary winding should be the inverse of this order. If it is likely that the coil will be used with all these breaks, some means should be provided for varying the number of windings, and if the coil be wound with three layers, and

an end be brought out to a switch so as to enable either one, two, or three layers to be used, it is quite sufficient.

Another plan is to wind with two layers so arranged that the two layers can be connected either in series or in parallel, or so that one layer can be employed alone. Then the coil can be worked to its full capacity under all conditions. This can easily be arranged by means of four terminals on the base. For high pressures the primary windings should consist of many turns.

A platinum break has advantages when portability is essential, as it renders the coil much more portable. A platinum break is also

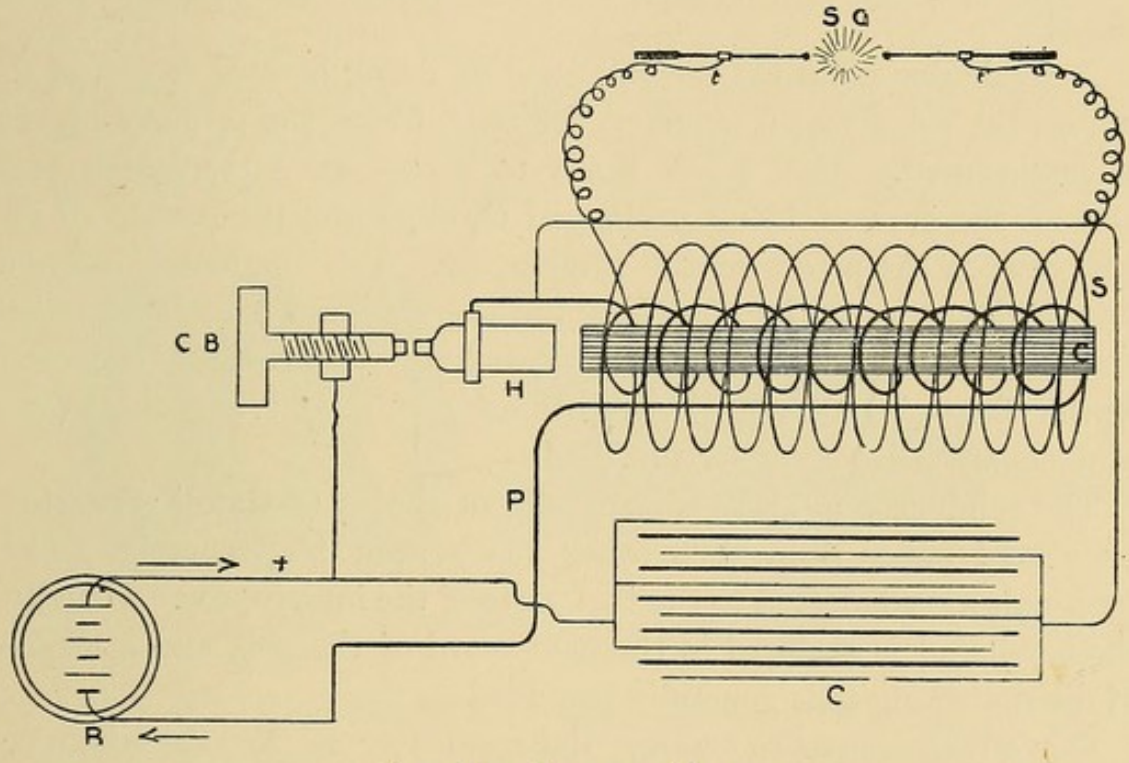


FIG. 16.—PLAN OF COIL.

CB, Adjusting screw of contact-breaker. H, Hammer of contact-breaker. P, Primary. S, Secondary. G, Soft iron core. C, Condenser. SG, Secondary terminals. R, Battery.

a useful addition to a coil as a reserve in case of the failure of the mechanical break.

An ordinary 12-inch coil that works perfectly well with a platinum break, will not give sparks of the full length of 12 inches with a high-speed break, unless a certain time is allowed for the current in the primary to rise sufficiently to produce full magnetization of the iron core, and if the break follows very quickly on the make the current may never rise to its full value. Its rate of rise will

be quicker if the pressure of supply is higher or if the self-induction in the circuit is lower, and therefore the number of turns in the primary must be reduced, or the voltage of supply must be increased, if the coil is to give its full spark-length with a rapid break.

This action can easily be seen with a motor-driven mercury break. For a given voltage of supply there is a certain speed of the motor which gives the best result. If the speed of the interruptions be increased when the applied volts remain the same, the magnitude of the exciting current can be seen to decrease and the secondary spark-length falls off, but by increasing the voltage the primary current can be maintained, and the full spark-length re-established.

A condenser improves the efficiency of a coil, because it serves to reduce the spark which occurs at the place where the primary circuit is interrupted. This spark tends to make the interruption less abrupt, the current being prolonged through the production of an arc between the points of the interrupter. The condenser reduces this tendency to arc by absorbing the energy which would otherwise appear in the spark. Moreover, the charge acquired by the condenser flows back through the primary coil, and has the effect of demagnetizing the iron core.

The condenser is made of two sets of sheets of tinfoil separated by waxed paper from each other and arranged alternately. The terminals are connected to the two parts of the interrupter. Usually the condenser is enclosed in the base-board of the coil, and a means of disconnecting it is generally provided.

It is advantageous to arrange the condenser so that the whole or part can be used. If it be divided so that one-third, two-thirds, or the whole can be employed, it is sufficient for medical purposes. The same coil can be made to work to its full power, using either an accumulator of 8 or 12 volts or a pressure of 100 volts from the street mains, if the primary windings and also the condenser be subdivided and adjusted.

Even large coils can be made to work with pressures as low as 4 volts if wound with a reduced number of turns in the primary, but they then take a much larger exciting current, so that the reduction in the number of accumulators necessary is accompanied by the necessity of increasing their ampère-hour capacity; with the larger current, too, the sparking at the break becomes greater.

To secure a good and lasting insulation of all parts of the coil is

essential. The iron bundle or core is wrapped in varnished tape, and, after being wound with the primary wire, is enclosed in a thick vulcanite tube. On the latter the secondary wire is wound in sections. A 12-inch coil may have seventy or eighty of these sections arranged side by side, and separated from one another by thin discs of ebonite.

The object of the sectional construction is to arrange the windings so that there shall not be any great difference of potential between contiguous portions of the secondary coil. The sectional construction has been developed to its highest degree in the 'jointless section' coils of Mr. Miller. Under this patent each 'section' consists of a single wire, coiled in a flat helix, and every one of these flat spires of winding has its corresponding insulating layer of waxed paper, so that the completed secondary coil may have from 700 to 1,200 single layer sections. The extra care thus taken in

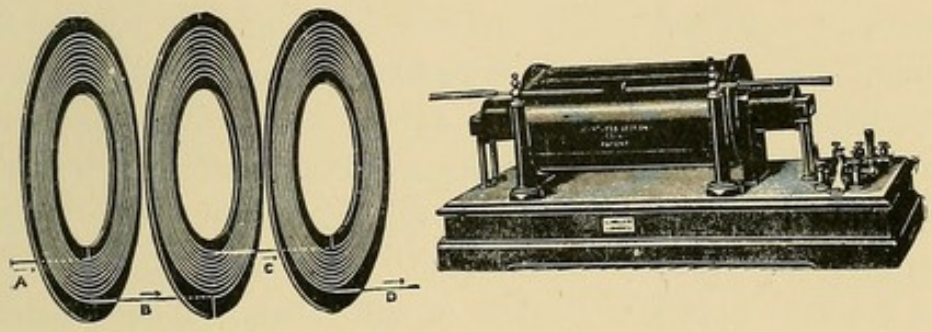


FIG. 17.—PLAN OF WINDING IN JOINTLESS SECTION COILS (LESLIE MILLER).

the insulation of the secondary serves to diminish very considerably the number of turns of wire necessary for producing a given length of spark, and thus reduces the weight and bulk of the coil. It also reduces both the ohmic resistance of the coil and its impedance, and the sparks of such a coil are consequently thicker, and the quantity of current in the discharges is increased. The output of a coil is commonly estimated by measuring its sparking distance in air; but it can be better estimated by observing the effect produced upon the length of spark when a capacity is connected to its secondary terminals. The reduction of spark-length which follows the introduction of a Leyden jar, or of any other condenser of given capacity, is less the greater the magnitude of current in the discharges of the coil.

Interrupters.—The break or interrupter is a factor of the greatest importance in the working of the induction coil. Various

interrupting devices are used, the simplest of them being the so-called vibrating hammer, or platinum interrupter. Its appearance is well known: an upright spring, armed at one end with a heavy piece of iron, is fixed on the base-board, so that the head of the hammer is exactly opposite the centre of one end of the core of the coil, at a distance of about $\frac{1}{8}$ inch. Fixed to the hammer, on the face away from the core, is a piece of thick platinum, and opposite this, on a brass pillar fastened to the base, is a screw carrying at its point a similar piece of platinum. The connections underneath the base-board are such that the current must pass to the primary coil through the junction of these two pieces of platinum. When the current magnetizes the soft iron core, it attracts the iron hammer, and so draws apart the two platinum points, and breaks the circuit. The current ceases to flow, the core is demagnetized, and the hammer falls back to its original position, when the current again flows into the primary circuit, and the process is repeated. The screw CB (Fig. 16) serves as an arrangement for adjusting the distance of the hammer from the iron core, while the tension of the spring is regulated by a screw that can be made to stiffen the hammer-spring, and thereby to hold the platinum points together against the attraction of the core, and thus to delay the break of circuit until the magnetism of the iron core has reached a proper degree of saturation. The greater the tension of the screw (provided it is not made so tight as to stop its vibrations altogether), the longer will be the sparks given out by the coil, and it is by regulation of the tension-screw that the working of the coil is adjusted to suit the various high and low tubes employed in *x*-ray work.

If a few experiments are made with a coil, it will soon be found that small adjustments of the tension-screw of the contact-breaker produce very great effects in the length of spark which the apparatus can be made to give out. Thus, with the contact-breaker spring quite loose, a 6-inch coil will give sparks of 1 or 2 inches only, and the sparks can be made longer and longer by progressively increasing the tension of the screw. When working with the coil the tension-screw must always be adjusted to suit the work which is required. Thus, at times it may be advantageous to screw up the tension-spring of the contact-breaker so tightly that the full strength of the battery is necessary to make it work. Under these conditions the primary current is broken only when the full current is flowing in

the primary, and the full magnetizing effect upon the iron core is developed. A sudden break of current then gives the maximum effect of which the coil is capable. When one is working with a tightened tension-spring the apparatus must be watched while at work, as the platinum points of the vibrator sometimes stick together, and the rush of current which would follow that accident might damage either the accumulators or the coil. It is also necessary to maintain the platinum contacts of the contact-breaker in good order. They burn away gradually from the effect of the

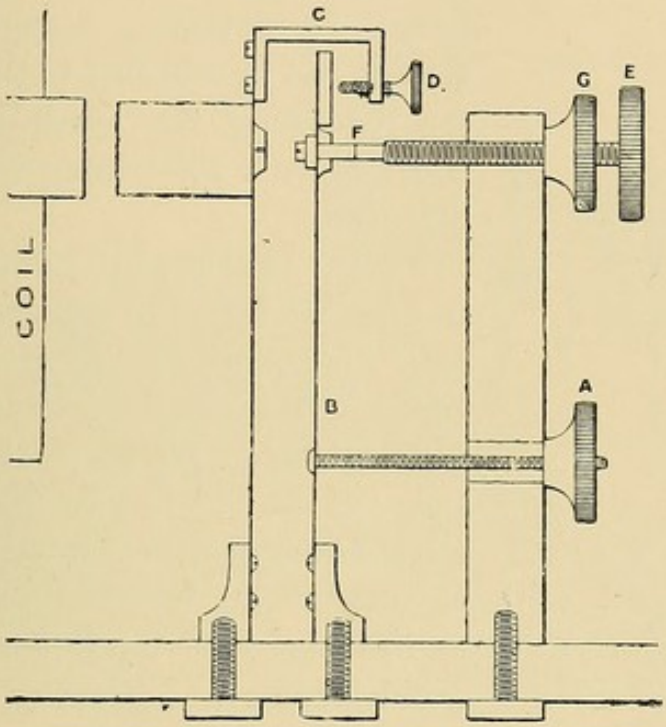


FIG. 18.—'VRIL' CONTACT-BREAKER (WATSON AND SON).

sparking, and their surfaces become uneven, and need to be filed from time to time to keep the surfaces flat, smooth, and clean. New platinum points can be fitted when the old ones are worn away.

The face of the iron hammer should be kept close to the end of the core.

Various improvements have been made from time to time in this form of interrupter. The 'Vril' contact-breaker represents a form in which one of the platinum contacts is carried by an intermediate spring (B, Fig. 18).

When in action, the movement of the hammer causes the point of the screw D to strike the top of B, so causing a sudden separation

of the platinum points at F. Consequently the break is more abrupt, the burning of the platinum contacts is reduced, while 'sticking' is almost impossible.

An interrupter of a similar character, made by Gaiffe, is shown in Fig. 19. The special feature of this interrupter, which is known as the Carpentier interrupter, is that, instead of a spring with a relatively large piece of metal at the end to serve as the hammer, there is a light strip of metal (D) balanced on its edge, and ready to fall forward or backward when influenced by the slightest force. By adjusting a spiral spring (C) tension can be supplied to this metal strip for regulating the spark-length of the coil. It is a good interrupter for portable sets.

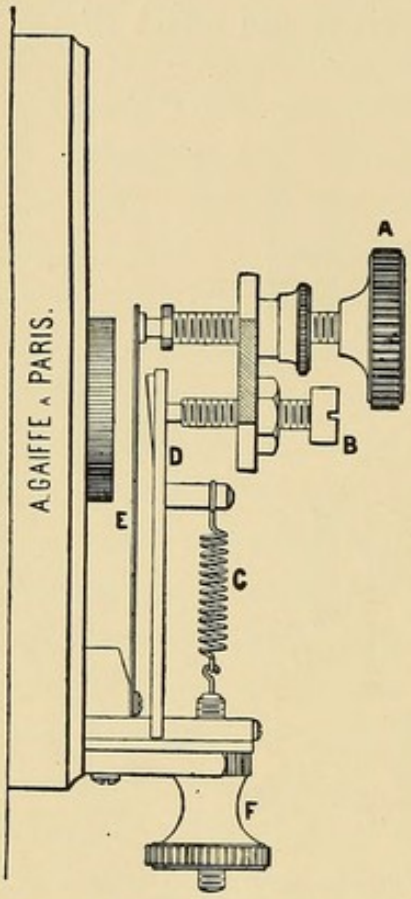


FIG. 19.—CARPENTIER-GAIFFE PLATINUM INTERRUPTER (MEDICAL SUPPLY ASSOCIATION).

Many workers with Röntgen rays still use the vibrating spring contact-breaker, and for photographic work this contrivance gives good results even with coils giving sparks up to 10 inches, when they are worked from a few accumulator cells, but for screen work this form of contact-breaker is not suitable, as it gives an irregular flickering illumination. More rapid breaks are necessary to produce a steady illumination of the screen.

With the introduction of higher pressures, as in using current from the main, the hammer interrupter should be abandoned in favour of mechanically-driven breaks.

All high-speed breaks require high electromotive forces to give good results. Consequently there is not much advantage in using a rapid break, unless the pressure of supply is raised in proportion.

With a vibrating spring contact-breaker the electromotive forces applied to the coil cannot safely be increased beyond a certain point, whereas with a sufficiently rapid break electromotive forces up to 100 volts, or higher, may be used, provided the speed of the break be increased in due proportion; and in this way we arrive at the direct employment of the electric-lighting mains (continuous

current) for working *x*-ray coils, a method which is possible only with rapid contact-breakers.

When current is used direct from the mains, it is necessary that the interrupters should work with certainty, as the continued safety of the coil depends upon their doing so.

Mechanical Interrupters.—Many forms of interrupters have been devised, and for purposes of description they may be arranged in groups. In the type devised by Foucault, about fifty years ago, the contacts were made and broken by a metallic rod dipping into mercury. If the mercury is covered by a layer of some non-

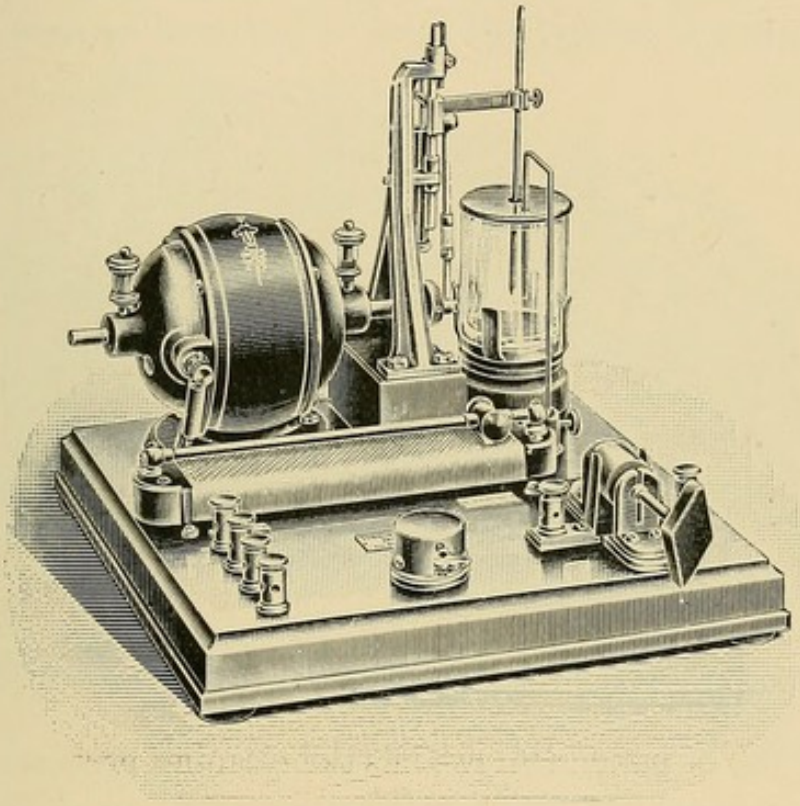


Fig. 20.—'Dipper' Break (Isenthal and Co.).

conducting liquid such as alcohol, the spark is quenched more effectually than in the air. This form of mercury interrupter is still in use, and in its modern forms the movement of the mechanism is usually effected by a small electromotor, the speed being varied by the regulation of the current supplied to the motor. The range of movement of the rod, or plunger, which dips into the mercury can also be adjusted, and the best conditions are obtained when the moving plunger is in contact with the mercury for a relatively long part of the period, and leaves the mercury when moving with its greatest velocity, which is when the crank actuating the plunger

is nearly at right angles to the surface of the mercury. These 'dipper' mercury breaks are useful for medium speeds of interruption and for currents of moderate magnitude.

For the high speeds which are necessary with high voltages of supply, rotary breaks are more widely employed. Mercury is used in most of them, but not in all.

In all motor-driven interrupters the break should take place beneath an insulating liquid, such as alcohol or paraffin oil. After a time these liquids become dirty, owing to the emulsifying effect produced upon the mercury by the churning movements of the apparatus. The mercury must then be cleaned and the liquid renewed. Alcohol (methylated spirit) is preferred by most workers,

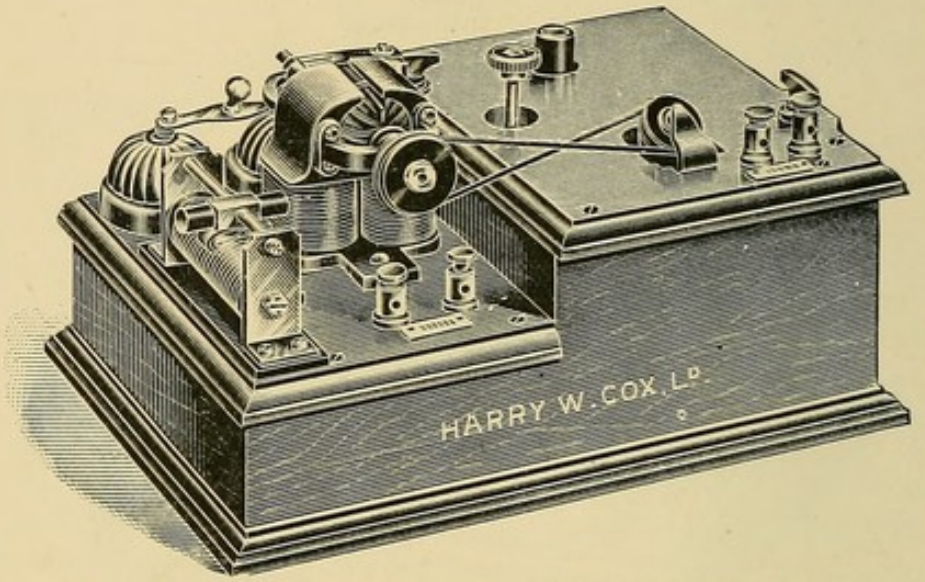


FIG. 21.—MACKENZIE DAVIDSON INTERRUPTER (COX).

because the use of paraffin oil renders the cleaning process extremely unpleasant.

Among the rotary breaks with mercury the Mackenzie Davidson break and the turbine break are the most widely used.

The former consists of an inclined metal axle with one or more projecting blades, which come into contact with the surface of a layer of mercury when the axle is revolved. It can be driven at a high speed, which is regulated by a variable resistance in the motor circuit. In the more recent patterns the moving blades are driven by a belt from the motor, and in this way the motor circuit is kept entirely separate from the exciting circuit of the coil. A special screw and plunger are used to vary the level of the mercury, and so to vary the depth to which the moving arm is immersed, and the duration of the contacts.

The turbine break (Fig. 22) is a motor-driven interrupter, in which mercury is propelled by a centrifugal pump in a continuous stream in a horizontal direction. The mercury jet strikes alternately on contacts and on insulating material. Several modifications of this interrupter exist. Thus, in some forms the mercury jet is stationary, and the interruptions and contacts are made by a deeply-toothed cylinder of metal, which revolves around it. In others the jet itself revolves, and in its revolutions projects the stream of mercury against a pair of conducting armatures, and so closes the circuit at certain intervals. The armatures are made in several sizes, to suit the pressures of

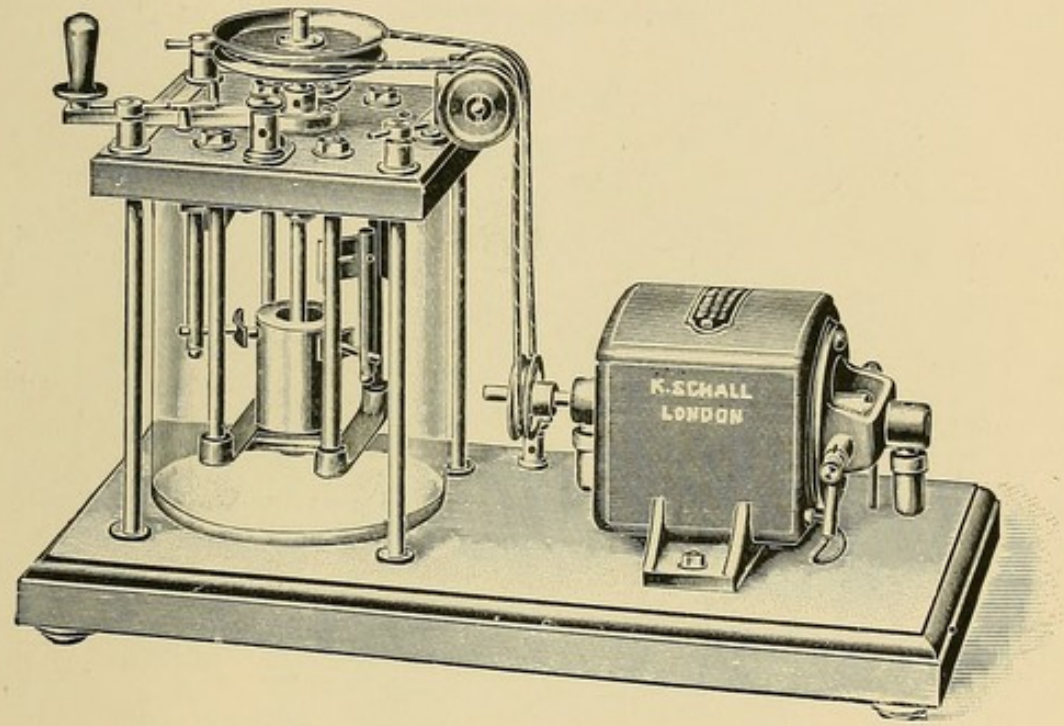


FIG. 22.—TURBINE JET INTERRUPTER (K. SCHALL).

current to be used, and the duration of each period of closure can be further controlled by the simple movement of a handle, which displaces one of the armatures. The number of interruptions per second is regulated by varying the speed of the motor. With this interrupter a steady light can be obtained on the screen. The turbine break will stand heavy work, and may be used for long periods without attention. The armatures gradually wear away, but they can readily be replaced. In the forms of turbine interrupter with fixed jet the duration of the contacts is varied by raising or lowering the revolving toothed cylinder, which has its segments tapered off below for this purpose.

These interrupters are to be found, with various modifications, in the catalogues of different instrument-makers. In some forms the motor is fixed in a vertical position, so as to drive with a straight belt, while in others the motor is horizontal, and the belt runs over guides. In Gaiffe's new form of jet interrupter the separate motor is abolished, and the current passing to the primary of the coil traverses four short electro-magnets fixed on the cover of the instrument, and these set in motion a soft iron disc which operates the mercury jet. This is a cheap and ingenious interrupter, and one which is likely to come into extended use.

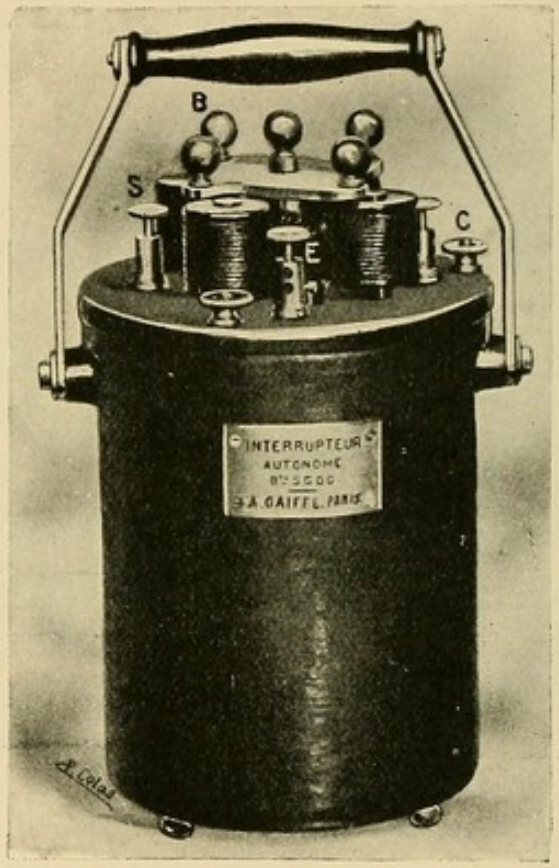


FIG. 23.—GAIFFE'S AUTOMOTOR JET INTERRUPTER (MEDICAL SUPPLY ASSOCIATION).

In the Contremoulins-Gaiffe interrupter, which resembles the turbine interrupters in general appearance, revolving sectors of copper make and break contact through copper brushes beneath a thick layer of insulating oil, and it is claimed that pressure of 200 volts may safely be applied to the coil through this interrupter. The rubbing contact surfaces may be amalgamated, but no large quantity of mercury is needed, as it is in the turbine break, and cleaning is therefore a simpler process, as little is needed beyond the periodical renewal of the oil. High-flash-point paraffin oil (which

extinguishes a light put into it) is the fluid used. The working of the interrupter is effected by varying the speed of the motor and by adjusting the regulator which controls the duration of the contacts, as in the motor-driven turbine break.

Most coils which are fitted with a hammer-break are also provided with a separate pair of terminals for use with motor-driven interrupters. To connect up the latter a pair of wires is led from these terminals to the terminals of the interrupter, and the contacts at the hammer are separated by a piece of wood or cork wedged

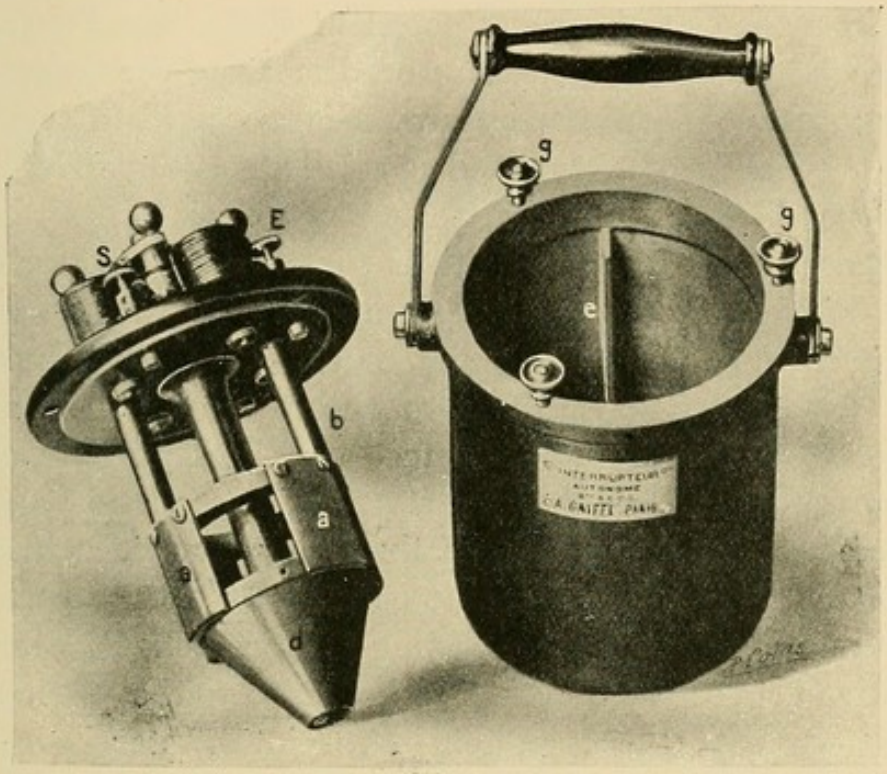


FIG. 24.—GAIFFE'S JET INTERRUPTER (INTERIOR VIEW).

E, Motor mechanism. The other letters refer to the contact pieces, screws, etc., of the mechanism. The case of the interrupter is of cast-iron, with internal flanges *e* (Medical Supply Association).

firmly between them. The wires from the battery or the main are joined to the coil as before. Instead of wedging up the hammer, its head may be detached, the other contact being withdrawn by a few turns of its screw. This mode of connection is adopted so as not to throw the condenser out of circuit.

Electrolytic Breaks.—An extremely interesting type of interrupter is the liquid or electrolytic break of Dr. Wehnelt. This depends for its effect upon the formation of bubbles of gas at the poles of an electrolytic cell through which a current is passing.

When one pole, which should be the anode, is of very small surface, the bubbles of gas formed there collect, and obstruct the continued passage of the current, and then again are dissipated, and so render the current intermittent, the interruptions following each other with extreme rapidity.

Wehnelt's break, as usually constructed, consists of a glass jar filled with dilute sulphuric acid of a strength of 10 per cent.; the kathode is a sheet of lead, while the anode is a platinum wire covered over, except at its extremity, which is deeply submerged in the electrolyte. The exposed end of the platinum projects into the acid from the end of a thick porcelain sleeve (see Fig. 25), and means are provided for increasing or decreasing the length of the projecting part. When the apparatus is arranged in series with the primary circuit of a coil, and a steady electromotive force is applied, the discharge through the circuit thus formed becomes intermittent, a peculiar shrill note is given out by the electrolytic cell, and streams of sparks are given off by the secondary coil. The liquid in the cell heats rapidly, and at a higher temperature than 60° C. the interrupter ceases to work. In working with this interrupter, the pressure applied must be at least 24 volts, and the apparatus works best at 60 to 80 volts. The condenser should be disconnected, as the coil works equally well without it at these high speeds of interruption. Care must be taken to ascertain the direction of the current before connecting up the Wehnelt interrupter. The positive pole of the source must be joined to the platinum. If connected wrongly, the operation of the interrupter is interfered with, and the platinum point will probably be destroyed. The platinum wears away at a moderate rate, but this is not a source of serious expense. It is probable that steam as well as oxygen is present in the bubbles formed at the anode, and the failure of the action when the electrolyte is hot is due to its imperfect condensation by the surrounding liquid under those circumstances.

A solution of sodium or potassium hydrate may be used instead of sulphuric acid for the electrolyte, and in this case iron can be used for the anode and kathode, and this saves the cost of the platinum, but increases the resistance of the cell somewhat. This modification has not yet come into practical use. A solution of magnesium sulphate or of alum, slightly acidulated with sulphuric acid, is said to work well, and to permit of the use of this form of interrupter at low voltages. E. Hauser, quoted in the *Archives of*

the Röntgen Ray (December, 1904), states that with a solution containing 20 per cent. of magnesium sulphate (specific gravity 1·305), acidulated with sulphuric acid, the interruptions begin at 10 volts. A solution of potassium bichromate has also been recommended for use in the Wehnelt interrupter.

When first applied to practical *x*-ray work the results obtained with the Wehnelt interrupter were not quite satisfactory, as the conditions for successful working were not understood, and in work-

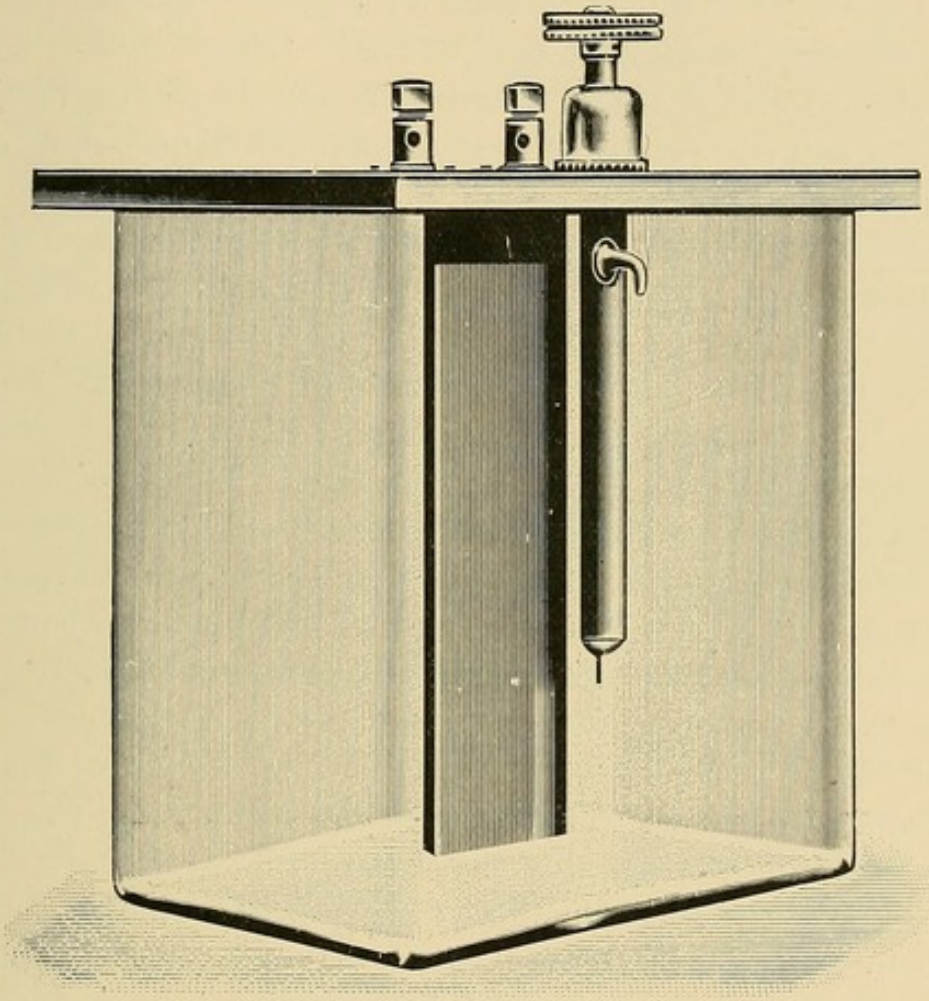


Fig. 25.—Wehnelt Interrupter (Sanitas Co.).

ing with the full pressure of the main the discharges were so rapid and powerful that the tubes were quickly destroyed. The electrolyte also became heated, and ceased working. In the modern forms of Wehnelt interrupter these defects have been corrected, and there is no doubt that this type of interrupter has the advantage of simplicity, and, if suitably regulated, it is a very useful interrupter for use with the continuous current mains. It is not suitable for use with batteries, because it requires large currents and high pressures.

To control the Wehnelt interrupter, one may vary the exposed surface of the platinum anode, or the pressure of supply in the primary circuit, or the degree of self induction in the primary coil.

By increasing the surface of the platinum the current is increased, and the rapidity of the interruptions diminishes; and by reducing the exposed surface of the platinum the opposite effect is obtained. A screw is the best arrangement for adjusting the length of the projecting platinum. As metal screws are likely to be corroded by the acid fumes, they should be made of ebonite. Several platinum anodes, connected in parallel, may be used. These can also be used independently, and if adjusted with different lengths of platinum, a simple switch will permit of easy selection of the one most suited for any given tube.

The frequency of the interruptions is also influenced by the pressure applied to the primary circuit. The higher the voltage the greater is the frequency, and *vice versâ*. To have good control it is, therefore, useful to employ some means of reducing the pressure of the main. According to the condition of the tube, as little as 30, or as many as 100, volts may have to be used. For extra high pressures the device of two interrupters in series has been recommended; and is said to work quite satisfactorily, and to reduce the consumption current. It is said that pressures of 200 volts can be applied to the coil by using this arrangement. The electrolytic interrupter may also be joined in series with a mercury jet break, and in this case the effect of the latter is to cut off the stream of impulses during part of the time. This relieves the strain upon the tubes, without impairing the action of the electrolytic interrupter.

The effect of the self-induction of the primary winding has been referred to already, and comes into especial prominence in working with the Wehnelt interrupter.

If the primary coils are arranged so that the layers can be connected in series, or in parallel, the self-induction can be adjusted to suit various conditions. When all the primary windings are in series the self-induction is highest, and the spark-length which can be obtained from the coil is short, and therefore suitable for soft tubes; when they are connected in parallel the self-induction is low, and the sparks are longer, and suitable for hard tubes. By varying the different factors—viz., the length of the anode, the voltage of supply, and the self-induction of primary coil—it is possible to obtain excellent control of the electrolytical interrupter, and the number

of sparks per second can be varied from about 10 up to 1,000. To obtain long sparks a low self-induction with a long platinum pin is used, and with a high self-induction and a short platinum pin the output of the largest coils can be lowered, so that it is suitable for soft tubes.

The heating of the acid is best met by the use of large volumes of electrolyte. Originally the glass vessels used contained less than 2 pints of acid, and after about half an hour's use the interruptions stopped through heating. By using vessels capable of holding several gallons of liquid the heating effect is reduced, as such quantities will stand an hour's use, or even longer, before reaching the critical temperature.

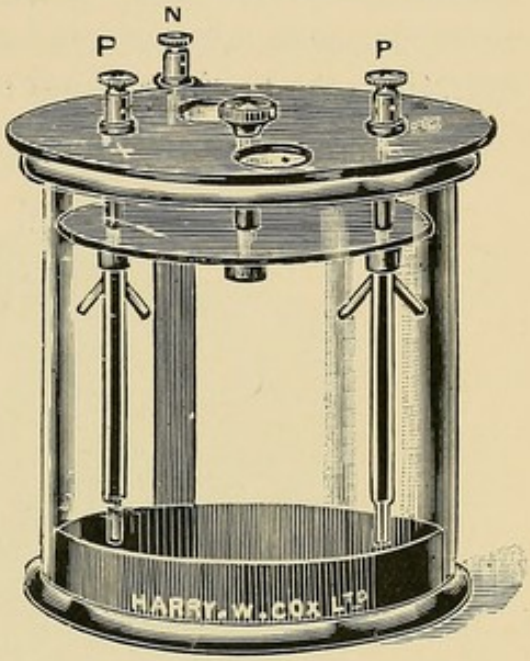


FIG. 26.—WEHNELT INTERRUPTER, WITH TWO ANODES (COX).

The cooling of the electrolyte by the circulation of cold water in a tube running through or around it has been proposed, but the complication introduced by this is better avoided.

The electrolytical interrupters make a peculiar noise when in action, but, as they require little attention after they have been properly adjusted and connected, they can be placed in another room if the noise be found disagreeable. They consume a good deal of current. Ten or twelve ampères or even more may be required.

In Wehnelt's apparatus the intermittent character of the discharge is due to the formation and dissipation of gas bubbles at the anode. There is a modification of the electrolytic interrupter, which is due to Caldwell, and independently to Simon, in which the formation of bubbles of gas is brought about at a point in the cell remote from the poles, and thereby certain advantages are secured. It consists of a cell containing dilute sulphuric acid and two plates of lead, which serve as anode and kathode. A partition of glass or porcelain separates the cell into two parts, each containing one of the metallic poles. This partition has a small hole, through which the liquids in the two portions of the cell communicate. At this narrow

opening the density of the current is very high, heating takes place, and bubbles of gas (steam) are generated there and break the circuit; the bubbles are almost instantaneously dissipated and as quickly renewed, the rate being in part determined by the size of the hole.

In its usual form the apparatus consists of a jar containing an inner cylindrical vessel of glass, suspended so that it does not rest upon the bottom.

Connections are made by means of terminals attached to two lead electrodes, placed in the inner and outer vessels respectively. When operating, the liquid is found to rise in the inner cylinder, which is

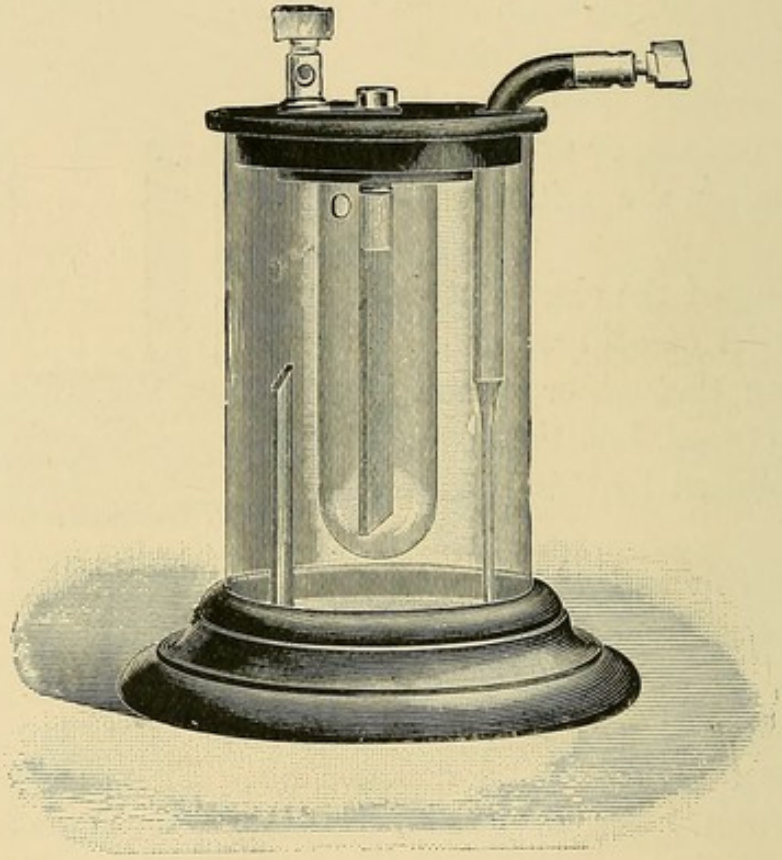


FIG. 27.—CALDWELL'S ELECTROLYTIC INTERRUPTER (SANITAS CO.).

accordingly provided with an overflow channel, through which the liquid returns into the outer vessel. As both poles are of lead and of large area, there is no special need to make the connections in one particular way as required for Wehnelt's form. This form of interrupter is most useful with pressures of 200 volts.

In the form of Caldwell interrupter contrived by Mr. Campbell Swinton, to regulate the current and the frequency of interruption, the size of the hole in the partition is varied in the following way: The inner vessel has a small hole about 3 or 4 millimetres in diameter at its lower end. Into this hole projects the tapering

end of a glass rod, which is attached to an adjustable screw, so that it can be raised or lowered as required. In this way the aperture can be partially closed by altering the position of the rod, and by this procedure the rate of the interruptions can be varied.

With these electrolytic interrupters the appearance of the discharge of a coil is considerably altered. The sparks at the secondary terminals follow one another so rapidly as to give the appearance of torrents of sparks passing simultaneously; and with pressures approaching 100 volts, and adjustment for the highest rate of interruption, the discharge has the form of a sinuous arc of pale yellowish-

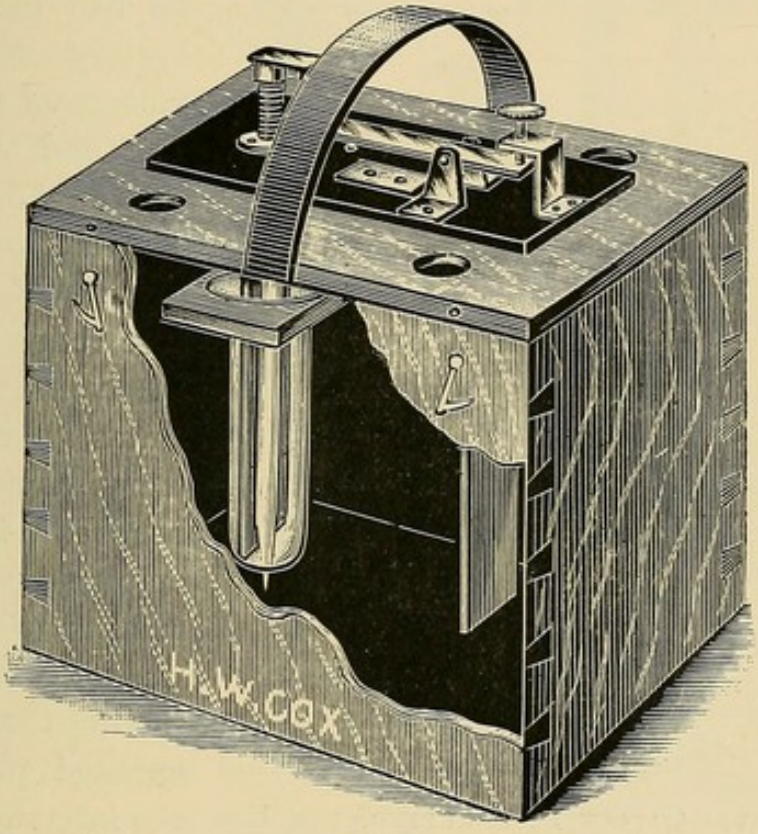


Fig. 28.—Caldwell-Swinton Liquid Interrupter (Cox).

green flame. For use with x-ray tubes it is best not to drive the rate of interruption too high, as few tubes will stand the strain. The higher the pressure the more rapid is the frequency of the discharge, and if it is tried to reduce the frequency by increasing the exposed area of the platinum at the anode, the current is likely to reach excessive magnitudes. To get the best work from an electrolytic break, it should be worked at as low a voltage as can be arranged to suit the tubes and coil employed.

Uses with Alternating Mains.—It has been noticed that there is a certain natural tendency on the part of electrolytic breaks to

transmit the pulsations in one direction more readily than in the other, and with a little care and management this form of interrupter can be used with the alternating mains. Dr. Dujon* was one of the first to describe his results in this direction, and states that with a Wehnelt interrupter the discharge of his 14-inch spark coil was absolutely unidirectional, so that reversing the commutator of the coil had exactly the same effect as if he had been using a battery current. The voltage of supply was 110, and the periodicity was 53 per second. The best results were given with the pressure reduced to 85 or 90 volts, with the ammeter in the primary circuit reading between 4 and 10 ampères. A certain amount of graduation was possible by adjusting the amount of exposed platinum in the interrupter.

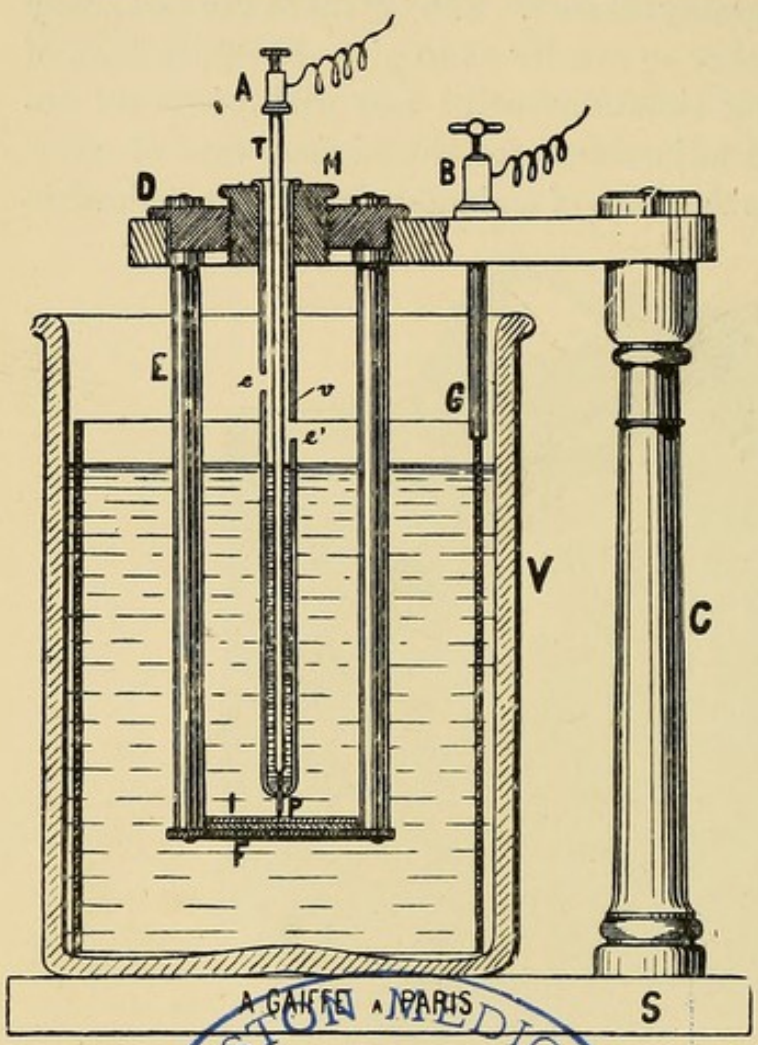


FIG. 29.—GAIFFE-GALLOT INTERRUPTER, FOR USE ON ALTERNATING CURRENT CIRCUITS (MEDICAL SUPPLY ASSOCIATION).

E is a frame suspended from the cover. A, The anode, terminates at P, and is enclosed in a sheath, except at its extremity, which rests on the plate below.

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Messrs. Gaiffe have constructed an electrolytic break, which works well on alternating current at 100 volts. They advise careful adjustment of the platinum anode so as to secure the best results, and their apparatus insures constancy of action for a considerable period of time by the following simple device: the projecting platinum P (Fig. 29) rests at its point upon a plate of mica, and as the point wears away the platinum slips further down by its own weight, and so preserves the original length of the exposed portion.

* *Archives d'Électricité Médicale*, April, 1901.

CHAPTER V

THE SECONDARY BATTERY OR ACCUMULATOR

Structure of an accumulator—Charging from a dynamo—From the direct current mains—From the alternating mains—Rectifiers—The aluminium valve.

Construction of Accumulators.—An accumulator is a vessel containing two sets of lead plates, called the positive and negative plates, and a solution of sulphuric acid of the strength of one part of acid to five or six of water. Each set of plates has a screw connection or terminal for the attachment of wires. In the smaller forms there are usually three plates, one positive and two negative, but there may be five, seven, eleven or more plates in each cell. Each cell is complete in itself, but for convenience it is usual to arrange four or six cells side by side in one receptacle, and the cells are then connected together in series—that is to say, the positive of one cell to the negative of its next neighbour, and so on, leaving at one end of the series an unconnected positive terminal, and at the other an unconnected negative terminal. The accumulators in common use for medical purposes are made of teak-wood boxes lead lined, and having wooden partitions to separate the cells.

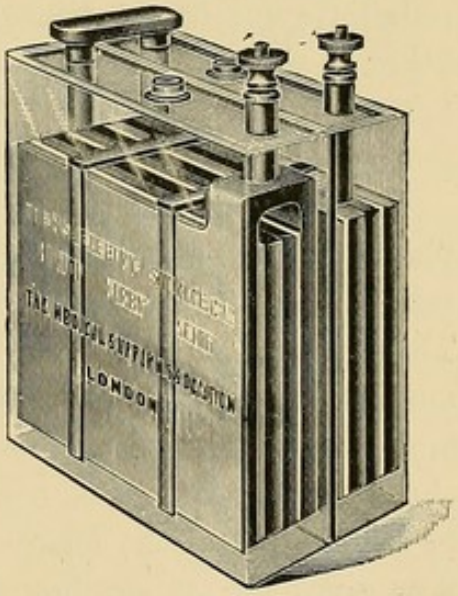


FIG. 30.—TWO-CELLED ACCUMULATOR (MEDICAL SUPPLY ASSOCIATION).

Both sets of plates are of lead, but as a result of their mode of preparation their surfaces are dissimilar, the positives being covered with a thick layer of dark chocolate-coloured peroxide of lead, while

the negatives are gray from a surface of spongy lead. In many types of cell the plates, or 'grids,' are full of small perforations containing the lead peroxide in the one case, and the spongy lead in the other. Positive and negative plates are kept apart by insulators of ebonite, or glass, or celluloid in the form of rods or buttons between the plates. If by accidental movement of the plates a positive should come into contact with a negative, that cell rapidly becomes destroyed.

An accumulator is charged by passing a current into it in the direction from positive to negative through the acid, and when charged it is able to give out a current in the opposite direction, until the energy stored in it by the charge has been expended. The electromotive force of a charged cell is a little over 2 volts, and as the cells in a battery are connected in series, the joint electromotive force of a freshly-charged battery of four cells is 8 volts, or a little over. In practical working the electromotive force is reckoned as 2 volts per cell.

An accumulator may be charged and discharged for an almost indefinite number of times if charging and discharging follow each other at short intervals, but an accumulator tends to deteriorate if left for many days in a charged condition, and deteriorates much more rapidly if left long in a discharged condition.

The capacity of an accumulator cell varies with the size of its plates, and is expressed in ampère-hours, meaning that it can maintain a discharge current of so many ampères for so many hours. Thus a 10-ampère hour cell can discharge at the rate of 1 ampère for ten hours, or of 2 ampères for five hours, and so on, and its charging must be in proportion. The charging and discharging current can be measured quite easily with an ampèremeter, or ammeter, and the current in ampères multiplied by the time of flow gives the ampère-hours.

Accumulators should not be charged or discharged at excessive rates. The proper rates are usually specified by the makers, but are not always adhered to by the users, and this is one reason for the short life of accumulators in careless hands. They should not be fully discharged, but as soon as their electromotive force falls below 2 volts per cell, they should be recharged as soon as possible.

In recharging there is not much danger of injuring them by too prolonged a charge. When fully charged any surplus energy applied is expended mainly in the electrolysis of the acid, though the

supports may be attacked if charging is excessively prolonged. A simple way of determining when a cell is fully charged is by putting the ear to the cell. If brisk effervescence can be heard the cell is fully charged. A slight effervescence may be heard before the charging is quite complete, and if the charging current is very small, the effervescence is not particularly loud even when charging is complete ; but a little practice will soon enable a judgment to be formed. There are other methods of determining when a cell is fully charged, but in the case of small medical cells these are more troublesome. The charging of a cell stores it with chemical energy, from which the energy is recovered in the form of electrical energy, just as is the case with an ordinary primary battery. The chemistry of an accumulator is by no means simple, and it will suffice to state here that during discharge the lead peroxide becomes reduced to sulphate, and during recharging this is reconverted into lead peroxide. The positive plates of a discharged cell are of a paler colour than those of one which is charged.

Charging of Accumulators.—In *x*-ray work the induction-coil is operated from accumulators or from the electric lighting mains direct. The use of primary cells for driving *x*-ray coils is not impossible, although so seldom practised that mere mention of it will suffice. Most primary cells are unsuitable because they have too high an internal resistance, and therefore cannot furnish currents of sufficient magnitude. The only practical cells which are made in sufficiently large size for the purpose are the Edison-Lalande, or copper oxide cell, and the bichromate cell. The latter is made in a convenient form, with a contrivance for lifting the plates out of the liquid during the periods of rest. The copper oxide cells consist of zinc and copper oxide plates in strong caustic soda solution. Their internal resistance is very low, and the cells in their larger sizes will give a discharge of 5 or 6 ampères. The electromotive force is only 0·8 of a volt, but with twenty cells a coil should work fairly well. The first cost of such a battery would be nearly £20, but when once set up the cells should give 500 ampère-hours before needing to be renewed. The plates do not need to be removed from the liquid, as they do not deteriorate when left to themselves on open circuit, and renewals of parts are not a serious expense ; but the handling of corrosive chemicals is a task to be undertaken only when unavoidable, and the static machine would probably be better for *x*-ray work than working with primary batteries.

Even when the electric lighting mains can be used for the major part of the work, the use of accumulators is still generally necessary when the *x*-ray apparatus is to be taken to the bedside of a patient. The typical *x*-ray outfit may therefore be considered to comprise an accumulator battery of four, six, or eight cells, and the management of an accumulator should be understood by anyone proposing to take up *x*-ray work. In some cases, of course, the accumulators can be sent away to be recharged, and where such outside recharging is easy to obtain, the employment of accumulators is simplified ; but under certain circumstances the cells may have to be charged at home, and the question of means must be considered. It is much more conducive to their long life if the accumulators are charged at home. Transportation of the cells at the hands of a careless porter or errand-boy is bad for them, and the charging is apt to be done too seldom if they have to be sent away every time it is required.

Practically the recharging of accumulators by primary cells is out of the question for serious *x*-ray work, and it is doubtful whether any medical worker adopts that method. For a small coil requiring less power to drive it, and for amateur work, the recharging from primary batteries might be attempted, but for such small work primary batteries might be connected directly to the coil.

Recharging from a private dynamo machine driven by power is a more practical way of working. Here the chief difficulty is that connected with the source of the power. Opportunities for using a water-motor, a windmill, or horse or man power for accumulator charging are exceptional, and need only be mentioned here. The use of a tandem bicycle, with the hind-wheel raised off the ground and belted to a dynamo, will be remembered in connection with Major Battersby's admirable work in the Soudan Campaign (see *Archives of the Röntgen Ray*, February, 1899), and the same means of charging cells has been used more recently in South Africa. The simplest outfit is a small gas-engine and dynamo, and if there is a considerable amount of work to be done—as, for example, in hospital work—the cost of a half-horse-power engine and dynamo is not prohibitive. For gas the cost is about £25, or for use with oil instead of gas about £35.* A number of makers can supply the necessary plant.

The dynamo plant once laid down will remain a serviceable

* The Gardner engines, Norris and Henty, 36, Upper Thames Street, E.C.

source of electricity, and with a set of accumulators it would suffice to run the engine for a few hours twice a week, to keep the battery in a fully-charged state for a considerable amount of *x*-ray work.

The dynamo must be shunt-wound (or compound-wound), and, unless specially designed to suit the battery it is to charge, there must be some form of regulating resistance to protect both the cells and the dynamo from damage by excess of current.

In charging an accumulator from a dynamo, the electromotive force of the charging source must be maintained steadily above that of the cells to be charged, for if this is not done the cells will discharge back through the dynamo, with a result quite opposite to that desired. For this reason the possibility of an unexpected stoppage of the machine must be borne in mind. To meet this danger automatic switches have been contrived, which at once cut off the cells from the dynamo circuit if anything goes wrong. This is necessary to prevent the charge already accumulated in the storage cells from running down through the dynamo circuit, to the probable damage both of dynamo and cells. When the dynamo is started its polarity should be verified before joining it up to the cells. A pole-tester can be used for this. Pole-finding paper is sold, which, when moistened and laid against a pair of conducting wires, turns purple at the negative pole. For medical men nothing is better than a piece of damped litmus-paper. This turns red (acid) at the positive, and blue (alkaline) at the negative pole. In testing the polarity of the mains, the operator must be careful to avoid accidental contacts of the wires, for carelessness in handling may lead to short circuits and the 'blowing' of the fuses.

A half-horse-power dynamo has a calculated output of nearly 400 watts, equivalent to 8 ampères at 50 volts, or 4 ampères at 100 volts.

If a dynamo is to be specially chosen for *x*-ray work, the most convenient pressure of supply would be 50 volts. At this pressure the strain upon the interrupting devices is much less than at higher pressures, and they therefore work better and last longer. A pressure of 40 volts is quite sufficient to allow of rapid interruptions and a steady light upon the fluorescent screen. Either Mackenzie Davidson's break or a form of the turbine break would be suitable, the motors of these breaks to be wound for use at the same voltage as that at which the coil is to be operated.

It is an advantage in some ways to be content with low pressures

to excite *x*-ray coils. When excited at 20, 30, or 40 volts there is not much trouble from the inverse discharges, or 'discharges at make,' of the coil, but at pressures of 100 volts these inverse currents become important, blurring the photographs and wearing out the tubes.

Charging Accumulators from Direct Current Mains.—In places supplied with direct current for electric lighting the accumulators can easily be kept in good order and fully charged by connecting them to the mains through a sufficient resistance, and leaving them there as long as may be necessary. An incandescent lamp is very generally used for the resistance. The more often the cells are charged the better it will be for them. Thus, if the accumulators have a capacity of 20 ampère-hours, and current is taken from them to the extent of 2 ampère-hours daily, it would be better to recharge to that extent every day, and not to wait until the cells were completely run out before starting to recharge them. The resistance is required to prevent the charging operation from proceeding at too rapid a rate. For example, the direct connection of a 10-volt accumulator to the 100-volt mains would be followed by such a rush of current as to destroy the cells. They would probably be raised to boiling-point in a very little while, unless the safety fuses in the circuit came into action to protect it.

The rate of discharge of the cells when working the coil can be measured with sufficient accuracy by an ammeter, and this figure (ampères) multiplied by the time of working (expressed in hours or minutes) gives the ampère-hours or ampère-minutes of the discharge from each cell; and, similarly, the rate of charge from the mains, in ampères or fractions of an ampère, multiplied by the time in hours, gives the ampère-hours of the charge. It is useful to know that on a 100-volt circuit a battery of eight or ten accumulators would be charged at the rate of about ½ ampère through a 16-candle-power lamp, and at twice that rate through a 32-candle-power lamp.

To charge from the mains with a lamp in series, the battery must be connected so that the current which goes through it must also go through the lamp. In the case of a lamp suspended by a flexible wire the conditions would be met by cutting one of the two strands of the double wire, and untwisting the cut ends for a few inches, so as to give sufficient length for connection to the two ends

of the battery. As one of the severed ends is positive and the other is negative, there will be a right and a wrong way of connecting up. In the former the direction of the current from the main will be opposed to that of the battery, the lamp will burn more dimly, and the battery will receive a charge. In the latter it will not receive a charge, but, on the contrary, it will discharge, reinforcing the current of the main, and the lamp in the circuit will burn too brightly. The effect on the lamp is the simplest guide to the right way of connecting in the battery, and when once deter-

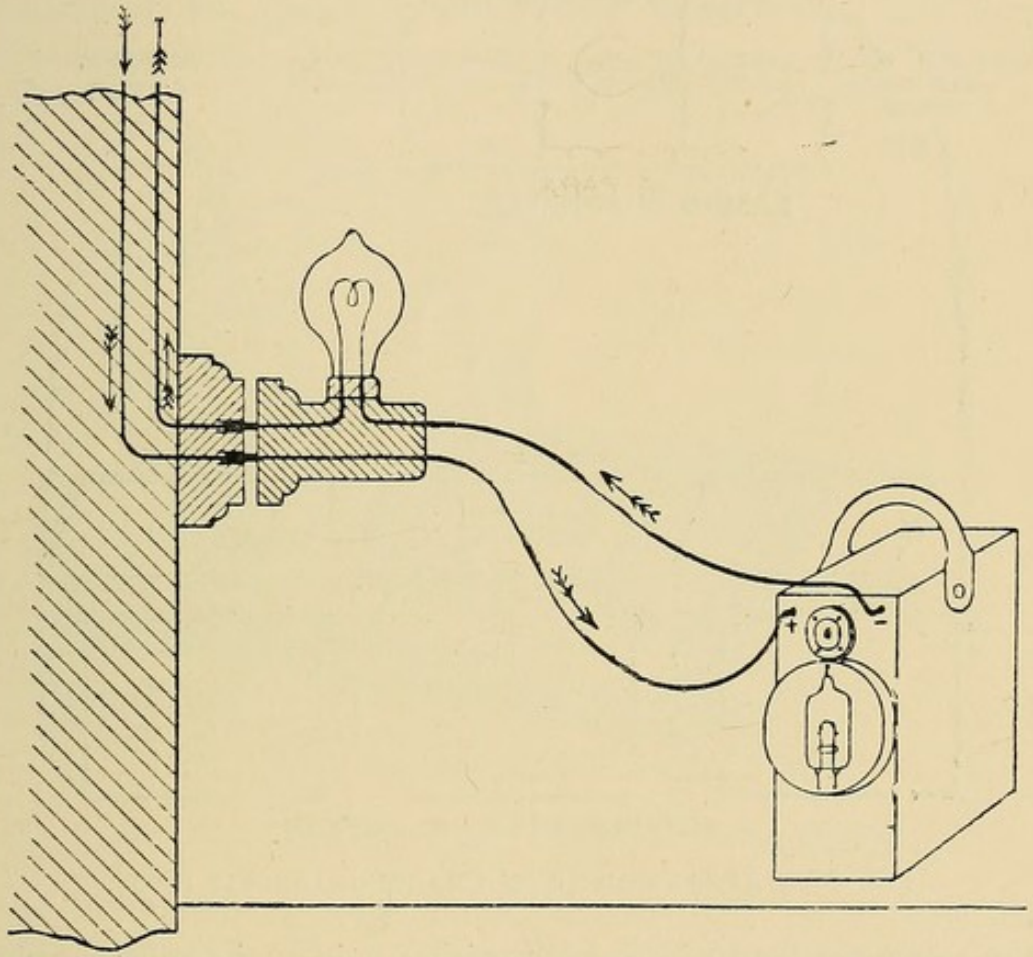


FIG. 31.—CHARGING THROUGH A LAMP-RESISTANCE (BIGGS AND CO.).

mined the ends may be marked in some way for future guidance. Another way of testing the polarity of the ends of wire is to use litmus-paper; the paper will be reddened where it touches the positive pole, and turn blue where it touches the negative.

If, instead of considering a flexible wire divided as just described, we consider a piece of electric light wiring enclosed in the ordinary wood casing, it will be seen that the same results can be obtained by removing a few inches of the casing cover; one of the two wires can then be cut, and the ends bent up a few inches apart, and

brought through holes in the cover, where they may be attached to binding screws for the sake of neatness. The battery can then be attached to these binding screws by means of wires when it is wished to charge, and when charging is not in progress the battery can be detached and removed, and the binding screws directly connected to each other by a neat connection of wire. The lamp will then be ready to give light, if required for that purpose.

Ready-made appliances for charging through a lamp can be bought at the instrument-makers. Usually they consist of a board carry-

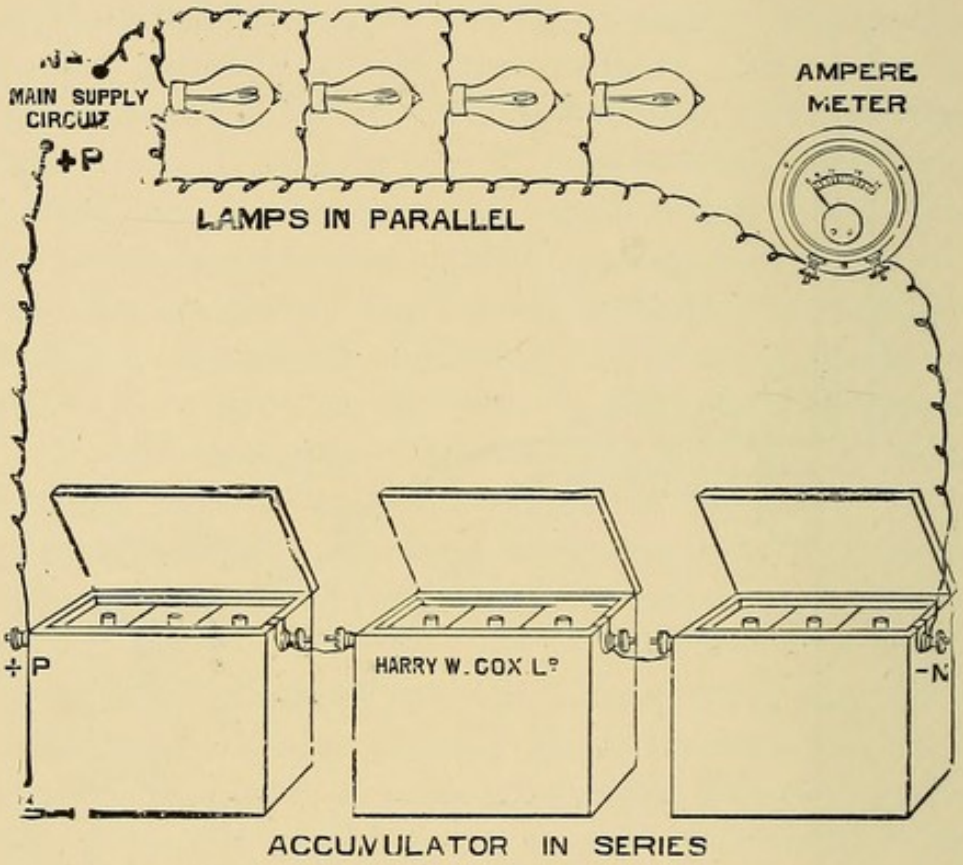


FIG. 32.—ARRANGEMENT OF CHARGING CIRCUIT (COX).

ing one or more lamps in sockets, with a pair of charging terminals, and a flexible wire with plug for attachment to wall-socket or lamp-socket, as may be desired. It is as well to bear in mind that with the ordinary two-prong wall-plug, and with the lamp-socket with bayonet-catch, there are two possible positions of insertion of the lamp or plug, and therefore the binding-screw, which is positive for one way, will be negative for the other. With *concentric* wall-plugs and screw socket-lamps the polarity is always the same. It is therefore useful to use these in preference.

Dr. E. E. Maddox* has described a form of lamp-resistance which

* *Trans. Ophth. Soc.*, vol. xxiii., December, 1902.

is very convenient for charging accumulators and for other medical purposes (Figs. 33 and 34), and he writes of it as follows :

'The lamp-resistances usually sold consist either of a series of lamp-holders for suspension from a lamp-socket, or of a box on which the lamps stand erect, side by side, and which is very apt to get knocked over. The design which I show is a kind of universal lamp-resistance, and is of a much more compact nature, consisting of a circular brass band, in which the lamp-holders are fixed radially, four of them being in parallel, while one, and also a pair of binding-screws, are placed in series with these four. Any lamp placed in one of the four contributes its current to the efferent

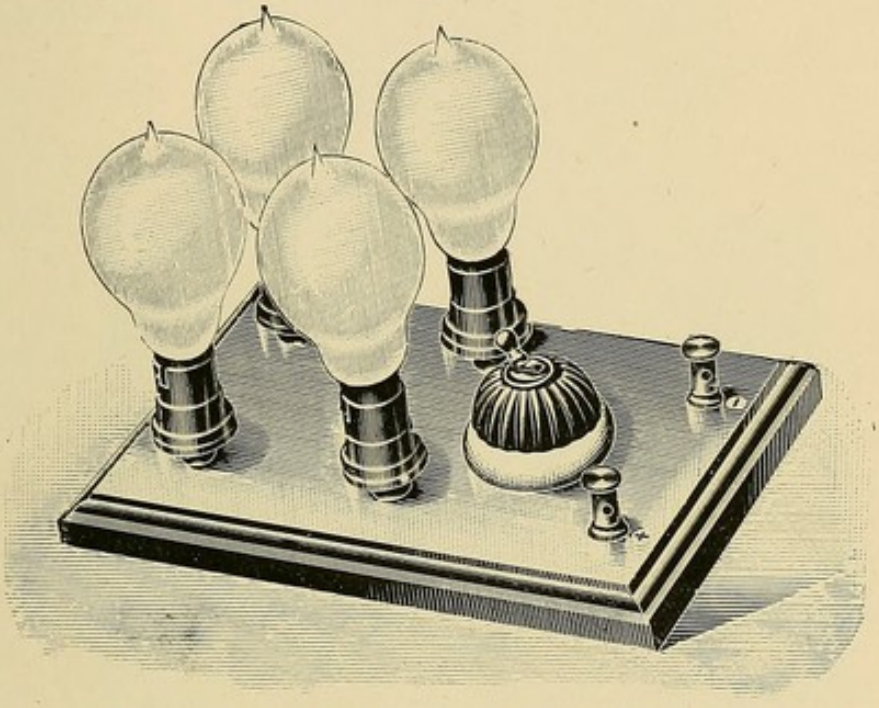


FIG. 33.—LAMP-BOARD FOR CHARGING (SCHALL).

cord, and by combining lamps of different candle-powers we can get almost any current we like. It hangs up, out of the way, from any lamp-socket.

'We only need to know how much current passes through each kind of lamp, and this is most easily calculated from the figures marked on all good lamps.

'It is a great convenience to have the choice of the binding screws, or of the bottom lamp-holder, for the attachment to whatever connecting cord we may have to use.'*

* The Stella Lamp Resistance is to be obtained of Miss Emily Long, 85, Crouch Hill, N. For tables of rates of charging of batteries from the mains, and much useful information, etc., see 'Portative Electricity,' by J. T. Niblett (Briggs and Co., Salisbury Court, E.C.).

Charging from Alternating Mains.—Accumulators may be charged from alternating current mains by the aid of certain devices, although alternating current cannot be used directly to charge accumulators. For example :

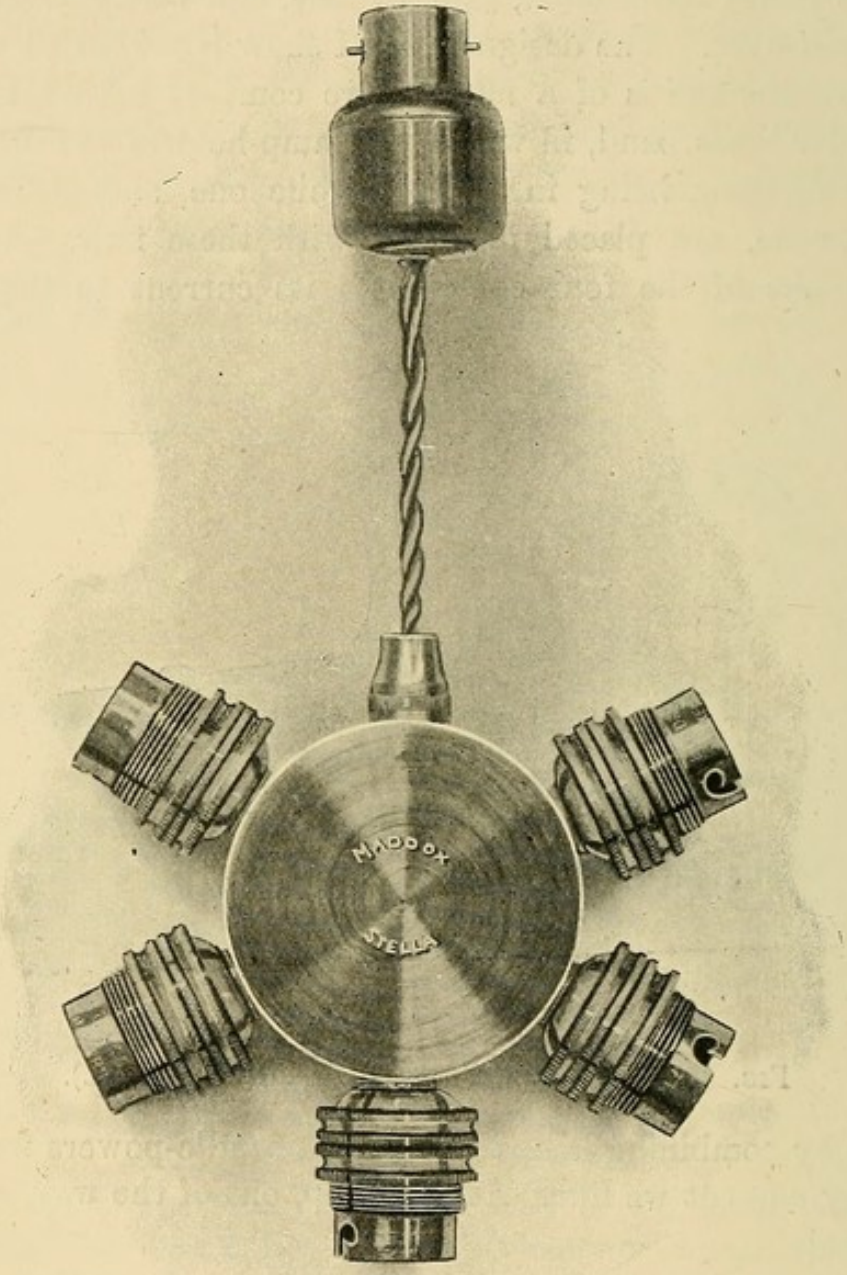


FIG. 34.—STELLA LAMP-RESISTANCE (DR. E. E. MADDOX).

1. An alternating current motor may be used to drive a direct current dynamo. The machines may be coupled by a belt, or they may be built upon one shaft.

In this method there is a conversion of electrical into mechanical energy, and a reconversion of mechanical energy into electrical

again. The method allows of a free choice as to the pressure and magnitude of the generated current, within the limits of the energy expended on the motor side.

2. A mechanical rectifier may be used, and by this is meant an instrument which periodically makes contacts, closing the circuit at such intervals of time as to transmit the impulses passing in one direction, while arresting or diverting those impulses which would tend to pass in the opposite direction. A rectifier, therefore, does not give a smooth flow of direct current, but a series of distinct impulses which all pass in the same direction. This may be quite as useful as a steady current for some purposes, such as the charging of accumulators.

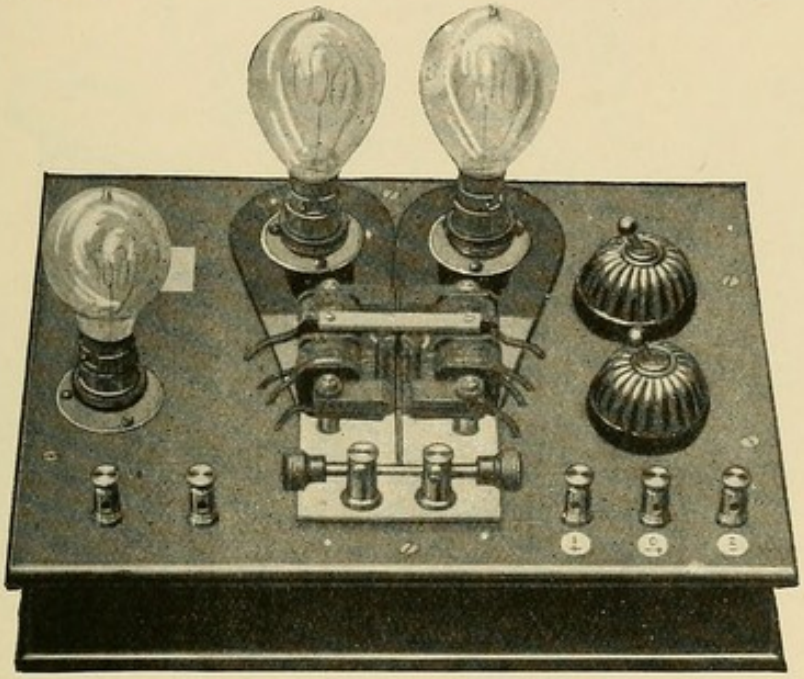


FIG. 35.—DR. BATTEN'S RECTIFIER (READ AND GALE).

There are several rectifiers in use among medical men, though none have come into very extensive use, because of the greater convenience of the chemical or electrolytic rectifier, to be described immediately.

Dr. Batten's rectifier consists of a short steel magnet, moving on a pivot between the poles of an electromagnet fed by an alternating current. It is attracted by each pole in turn, as the direction of the current changes, and in its excursions it makes contact with each of two studs, and so closes the circuit of utilization. It is so arranged as to permit of the utilization of both semi-periods of the alternating current, so that, for example, two sets of accumulators can be charged simultaneously (Fig. 35).

A very ingenious detail of Dr. Batten's rectifier is the use of a tinfoil condenser in the circuit of the electromagnet, and of a self-induction coil in the rectifier circuit. This arrangement reduces the amount of sparking at the contacts, and is valuable on that account.

An apparatus of the same type, on a larger scale, is made by Messrs. Siemens Brothers, and can be used for charging accumulators, or as a synchronous interrupter for driving large induction

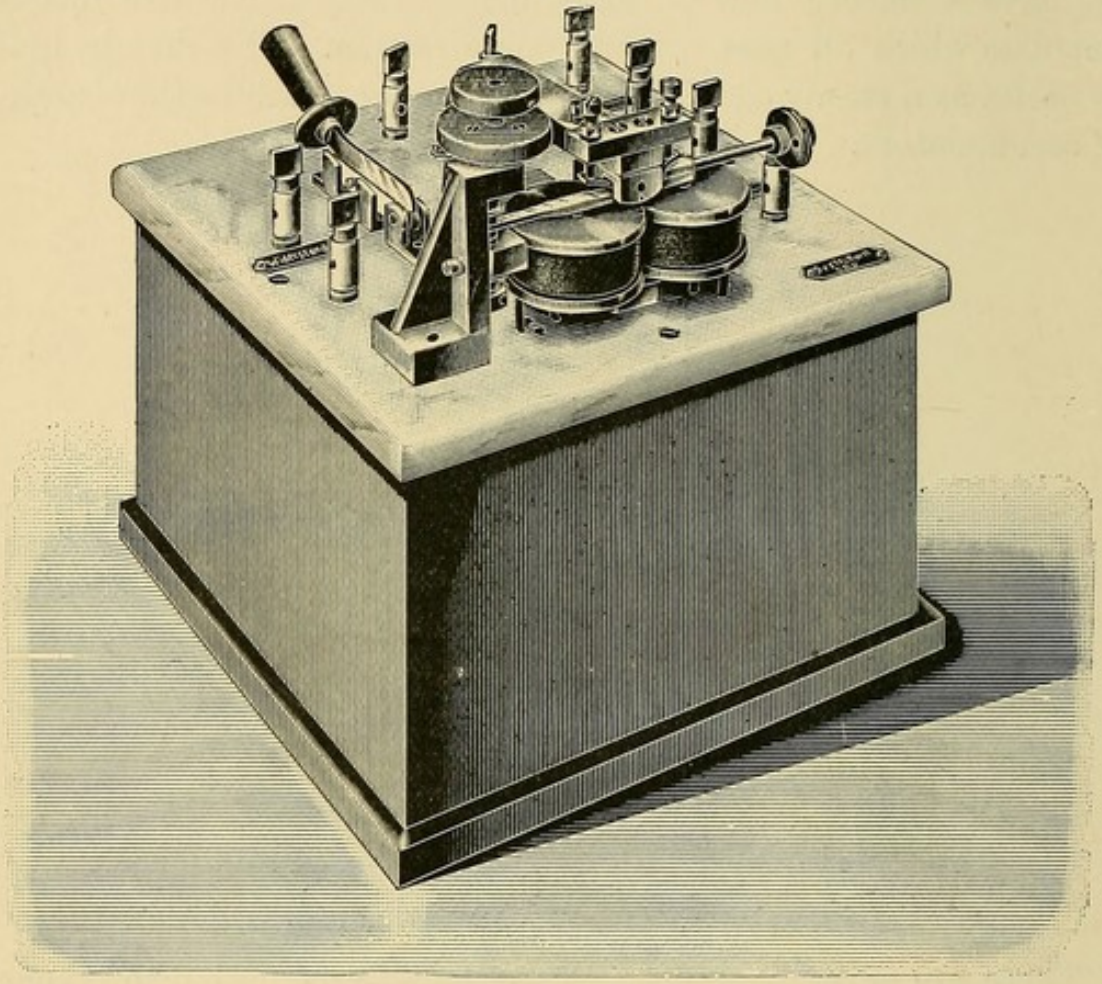


FIG. 36.—SIEMENS' RECTIFIER (SCHALL).

coils. In the latter case the contacts and interruptions are arranged to take place near the maxima of the alternating current waves, and the contact surfaces of platinum are massive, to carry large currents and to withstand the sparking. In this form the instrument serves at once as rectifier and as interrupter, and makes the operation of coils from the alternate current mains a simple matter. Dr. Batten has proposed to employ his rectifier in the same way, and the rectifying interrupter of Villard is a similar device, which is in use in France (Fig. 36).

The rectifiers just described work by means of a vibrating tongue, which oscillates in synchronism with the periods of the alternating current. Other types of rectifier operate by means of a revolving commutator fixed on the axle of a synchronous motor. The rectifier of Dr. Reginald Morton is a beautifully-made machine of this type, with a self-starting mechanism for bringing the motor into synchronism. It has a massive commutator, and is able to rectify currents of large magnitude in a very perfect manner. It is made by Messrs. Newton, and the same firm also makes a rectifying interrupter of a different kind, which consists of a small motor fitted with one or two cranks on the axle. These carry plungers making contact with mercury cups, as in the 'dipper' break, and

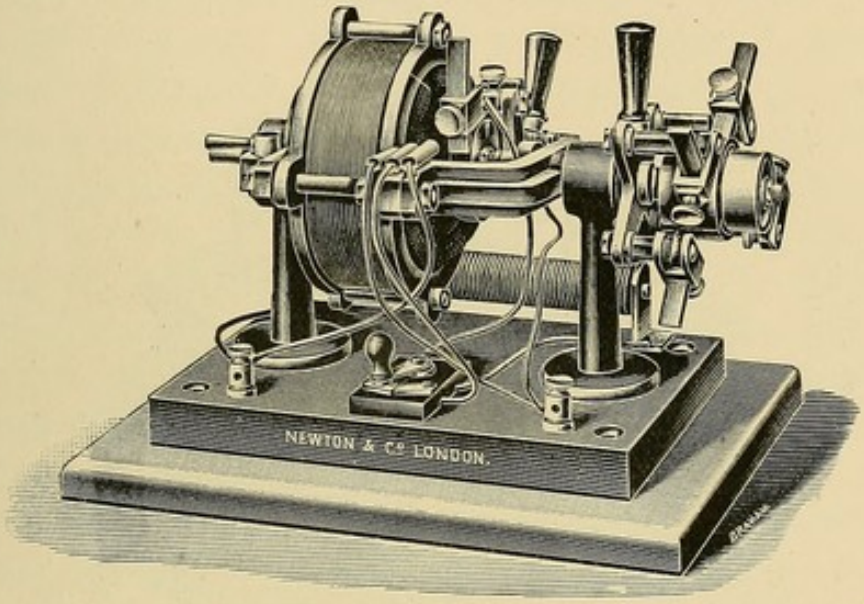


FIG. 37.—DR. MORTON'S RECTIFIER (NEWTON AND CO.).

the instrument can be adjusted to work either as a rectifier or as an interrupter for working large coils. It starts easily into synchronous movement with a touch from the finger (Figs. 37 and 38).

3. A rotary converter may be used. A pair of rings and collecting brushes are fitted on the axle of a direct current motor. The rings are insulated from the shaft and from each other, and are connected to two opposite segments of the commutator—*i.e.*, to opposite points of the armature winding. When such a machine is running in synchronism with the pulsations of the alternating current, it acts as a motor when fed with alternating current through the brushes to the rings, and at the same time a steady direct current can be drawn from the brushes of the commutator proper.

The difficulty with this apparatus is the starting up to synchronism of the motor; moreover, the small machines likely to be used in medical practice are somewhat sensitive to changes of load, and they may be thrown out of step at a critical moment, and stop. The starting difficulty is not insuperable; it may be overcome either by a hand-wheel, or by running the machine up to speed as a direct current motor with current supplied to the commutator from accumulators, which are cut off again when the motor is in step and ready to receive the alternating current. The accumulators can be recharged from the rotary converter when it is in action.

By means of a step-down transformer the pressure in the circuit

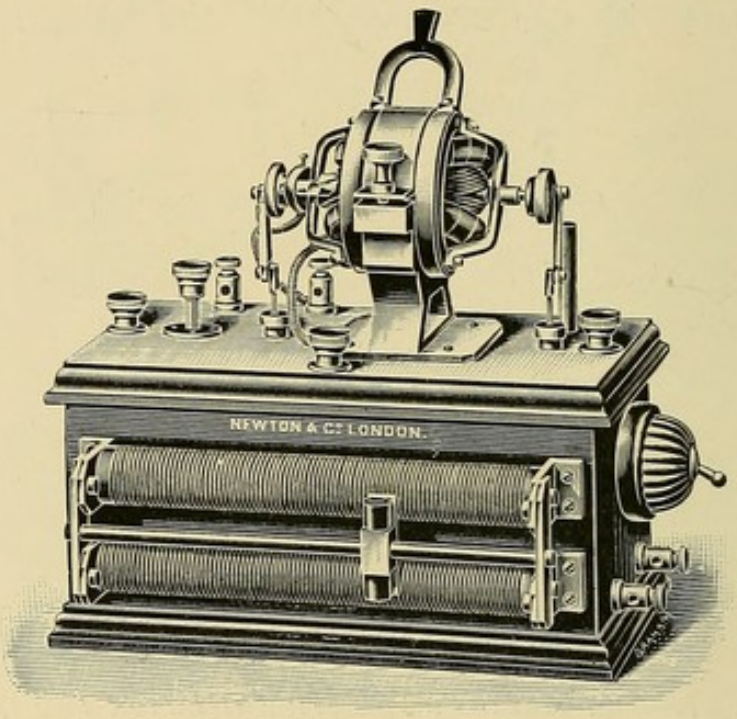


FIG. 38.—WRIGHT'S RECTIFYING INTERRUPTER (NEWTON AND CO.)

to be rectified may be adjusted to suit the particular case. Thus, for charging a few accumulator cells a current of 1 ampère at 100 volts could be changed to one of 5 ampères at 20 volts before rectification, with advantages from the point of view of economy and of convenience.

The Aluminium Electrolytic Rectifier.—This is a most valuable contrivance for obtaining direct currents from the alternating mains. It is far more suitable for medical purposes than any mechanical rectifier, as it has no moving parts, and can be left unwatched for hours with safety. Its value depends upon a peculiar property of certain metals, particularly of aluminium and magnesium, by which they offer a very high resistance to the passage of a

current when they are made the anode of an electrolytic cell, although as kathode they offer no such resistance. Accordingly, an electrolytic cell having aluminium for one pole and carbon or a metal for the other pole will tend to arrest the passage of an alternating current through it in one direction, while readily permitting a flow in the other direction. This property of aluminium has been known for many years, having been discovered by Buff in 1859. Its practical application to alternating currents was suggested by Ducretet, Graetz, Pollak, and others, and in recent years the aluminium cell has been extensively studied and very much improved for practical purposes.*

A simple aluminium cell can be made of a rod of aluminium immersed in a jar of ammonium phosphate solution, with a sheet of iron for the other pole. With such a cell arranged in series with a resistance—as, for example, with a lamp-resistance—the alternating mains can be used to charge an accumulator, if the aluminium cell is so connected up that the direction of flow from iron to aluminium in the cell is towards the positive terminal of the accumulator. The rectifying action is trustworthy at 100 volts. On mains at 200 it would be economical to use a transformer to reduce the pressure to 50 volts, thus giving 4 ampères for one, for otherwise two aluminium cells coupled in series must be used, though they are less efficient when used in that way.

A direct current ammeter in the circuit will give readings of the mean charging current, and as half the impulses are arrested by the cell, the readings will be half of those for which the candle-power of the lamp is rated; thus, with a 32-candle power lamp on 100-volt mains carrying 1·2 ampères, the accumulator will be charged at the rate of about ½ ampère, if allowance be made at the rate of 0·1 of an ampère for loss in the system.

By using a combination of aluminium cells both phases of the current can be utilized. Fig. 40 shows a simple arrangement by which two cells can be used. The aluminium cells K, K, are oppositely arranged on two branches of one of the conductors of an alternating circuit, while the other conductor is joined through a resistance to the middle point of a set of accumulator cells. It will be seen from the diagram that the impulses of current will pass alternately into one or other of the accumulator sets, and will charge

* See the *Electrician*, October 14, 1904, for an interesting account by A. Nodon.

each in turn. By this arrangement the aluminium cells are not called upon to resist the full back electromotive force of the impulses in the wrong direction, for one or other of them is always open to the easy passage of current. Thus the wear and tear of aluminium is reduced, and the heating of the cells is also lessened. This is useful, because the efficiency of the valve begins to fall off when the temperature rises above 70° F. The size of the cell should be proportionate to the magnitude of current to be rectified,

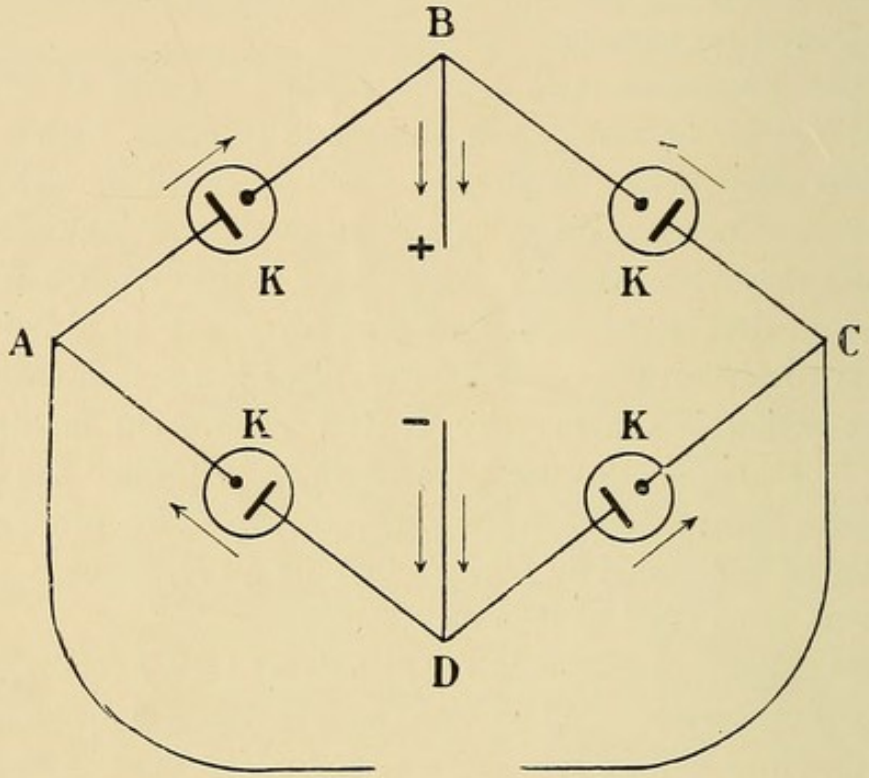


FIG. 39.—ARRANGEMENT OF FOUR ALUMINIUM CELLS, UTILIZING BOTH SEMI-PHASES OF THE ALTERNATING CURRENT (H. K. LEWIS).

K, K, Aluminium cells. The arrows show the direction from iron to aluminium in each cell.

in order to avoid overheating of the electrolyte, and the area of the aluminium must be kept small, as a certain density of current is necessary to give a good valve effect.

The disposition of cells shown in Fig. 39 is due to Graetz, and is an application of the principle of the Wheatstone's bridge, in which resistances are balanced against each other. Four cells are arranged in a circuit, as shown at K; the direction from lead to aluminium is indicated by the arrows. The alternating current is applied at A and C. No current can pass in either direction, for it is opposed

by one or other of the aluminium cells; but if B and D be connected a current will flow from B to D. When A is the positive pole, the flow will be by A, B, D, C, and when the sign of the electromotive force changes, and B is positive, it will flow by C, B, D, A—always, therefore, from B to D, through any circuit joining B and D. The system may be regarded as a Wheatstone's bridge circuit, in which the resistances automatically change with the changes of sign of the alternating electromotive force applied at A and C.

The Nodon valve and Pollak's rectifier are practical arrangements of aluminium cells on this principle, and they answer quite well for accumulator-charging, and may also be used to supply current for driving motor interrupters for coils, and for working the coils

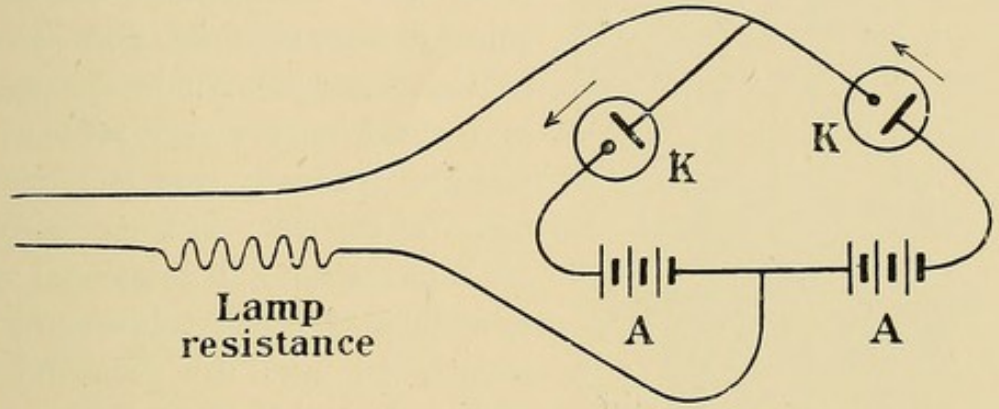


FIG. 40.—ARRANGEMENT OF TWO ALUMINIUM CELLS FOR ACCUMULATOR CHARGING (H. K. LEWIS).
K, Aluminium cells. A, Accumulators to be charged.

themselves. The current given out by these forms of rectifier is not smooth, but for most practical applications it answers almost as well as if it were.

A large number of solutions have been proposed for the electrolyte. The choice among these will be partly governed by the nature of the metal used for the second pole of the cell, for it is desirable that this should not be attacked through electrolytic action. Among the chemicals which have been suggested are alkaline sulphates, especially ammonium sulphate, ammonium phosphate, ammonium chromate, double tartrate of potassium and sodium (Rochelle salt), and many others. Nodon states that for magnesium poles the best effect is obtained with an electrolyte of ammonium fluoride. In general the salts of potassium and sodium are more likely to corrode the aluminium than are those of ammonium.

The compound used in the commercial form of the Pollak rectifier is a weak solution of alkali.

Nodon has stated that neutral ammonium phosphate is the best salt for the electrolyte, and in the Nodon valve this compound is used, and the aluminium poles are alloyed with zinc. It is doubtful whether this addition is necessary. In its original form the Nodon valve was made of four iron cylinders, supported side by side in a wooden frame. The aluminium was in the form of short, thick rods, inserted from beneath through rubber corks, and the wire connections were also below. The arrangement in its present form is different, though the principle is the same. When the cell has been in action for a time the ammonium phosphate solution loses ammonia and becomes acid. Some aluminium phosphate is formed, and a crystalline precipitate gradually incrusts the interior of the cell. If the electrolyte be kept alkaline by occasional small additions of weak solution of ammonia, to take the place of the water lost by evaporation, this incrustation will be much diminished, and instead there will be merely a slow precipitation of alumina as an amorphous sediment. Chlorides are unfavourable to the valve effect, and distilled water must be used in preparing the electrolyte.

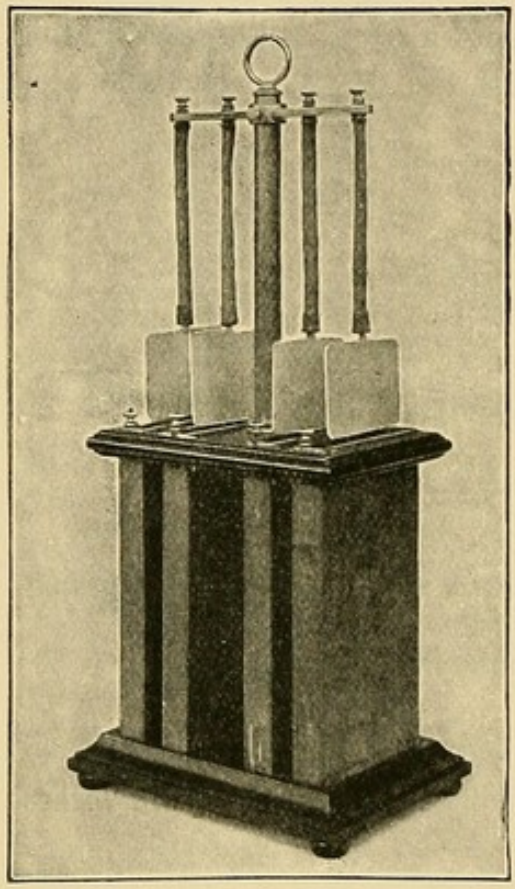


FIG. 41.—POLLAK'S ALUMINIUM RECTIFIER (WATSON AND SONS).

Whatever salt be chosen for the electrolyte, it must be used in strong solution to obtain the maximum conductivity of the electrolyte, and to reduce the thermal effect of the current. If iron be used for the other pole of the cell, it is not attacked by the electrolyte. If lead be used it becomes covered with a layer of lead peroxide.

As the writer has used a simple form of aluminium cell for recharging accumulators for over twelve months, and can therefore

recommend its use confidently, the following details of its construction may be useful:

The accumulators to be charged are two four-cell accumulators of the E. P. S. portable medical type. The aluminium cells consist of two cylindrical glass battery jars, 12 inches in height and 4 inches in diameter. The aluminium poles are rods of that metal, about as thick as an ordinary lead-pencil, and 10 inches long. They are fitted above with a binding-screw, and pass through corks which in turn fit into holes in a flat strip of ebonite, which rests on the top of the jar. The other poles of the cell are pieces of hoop-iron 10 inches long and $2\frac{1}{2}$ inches wide, fastened by a battery clamp to a piece of wood, which rests on the top of the jar and holds them steady.

The resistance used to regulate the current is a 32-candle power lamp, the pressure of supply being 100 volts; the current through the lamp is therefore 1·2 ampères, and this is distributed by the two aluminium cells to the two accumulator batteries, each of these in turn receiving an impulse of current, followed by an interval, while the other accumulator is receiving its charge. The mean current fed to each accumulator in a given time is therefore 0·6 of an ampère, equivalent to a current of 1·2 ampères for half the total time.

The cells just described may be run continuously for many hours, without becoming too hot. For larger currents larger cells and a greater volume of electrolyte would be necessary. About once every three months the cells should be dismounted, the solution filtered and replenished with a little more ammonium phosphate solution, and the connections and the plates freed from any incrustations which may have formed.

If the 32-candle power lamp is replaced by a 16 or an 8 candle power lamp the current is seen to fall off more than it should theoretically do, and it appears that the valve action is less effectual when the density of current per unit surface of aluminium is below a certain minimum. One may easily satisfy one's self that this is the explanation of the effect observed by noting the effect of partially withdrawing the aluminium rods from the liquid. If this be done while the ammeter readings are watched, the current will be seen to improve as the immersed surface of the aluminium is reduced.

CHAPTER VI

THE DIRECT APPLICATION OF THE MAINS

Direct current mains—Shunt-resistance regulation—Alternating mains—The use of transformers for the operation of *x*-ray tubes.

THE existence of an electric light supply, while simplifying the process of charging accumulators, at the same time does away with the need of accumulators to a great extent. The direct working of coils from the electric light mains will generally be preferred whenever the opportunity exists for doing so, though there will still be the need for accumulators in cases where the apparatus has to be transported to the bedside.

The gradual extension of electric lighting and of *x*-ray work in hospitals and among private practitioners has led to much inquiry as to the best way of working coils from electric light mains. In dealing with the question it is necessary to consider the circumstances under which the coil is to be used, and also the qualifications of the operator who is going to undertake the work. The apparatus which would be the best in skilled hands might not be so suitable for use by occasional and less experienced workers.

Direct Current Mains.—In a place supplied by direct current mains the possible modes of utilizing them are as follows:

1. Accumulators may be charged and then employed to operate the coil by means of a hammer interrupter and six or eight accumulator cells (12 to 16 volts). This arrangement is portable, and may be transported easily to the bedside.

2. Some form of motor-driven break—as, for example, the Mackenzie Davidson interrupter (Fig. 21)—may be used instead of the hammer, in which case sixteen to twenty accumulator cells (32 to 40 volts) may be utilized with advantage. Apart from first cost the charging and maintenance of twenty cells is as simple as the charging of eight cells, and the high-speed break greatly improves

the results, especially for screen-work. The motor employed may either be wound to work from the accumulators which are used for the coil, or it may be wound to work on an independent circuit at the full pressure of the mains.

3. Accumulators may be discarded, and the mains may be connected direct with the apparatus through a shunt-resistance, which permits of a wide range of pressure being employed. This plan is valuable when extra high-pressure mains (200 volts and upwards) have to be utilized.

4. With pressures of 100, 105, or 110 volts, the turbine break may be used direct on the mains, without the need of a shunt-resistance to reduce the pressure. By attention to details of speed of break and duration of contacts it is possible to obtain excellent regulation with the turbine break, and if further control is wished for, it can be had by the addition of a simple series resistance in the primary circuit.

Inasmuch as simplification of apparatus is of great importance in all electro-medical work, the combination of a rotary break driven by the direct current main either with or without a shunt-resistance will be generally preferred by skilled operators.

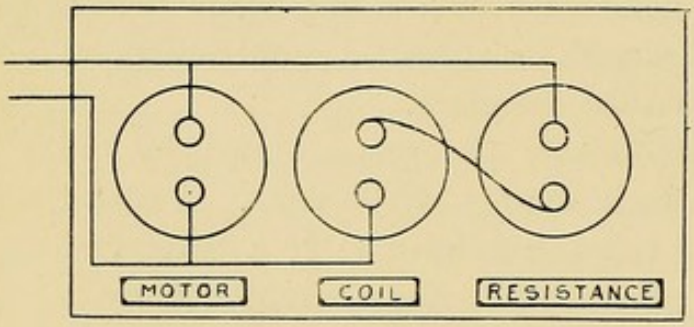
The arrangement last described is the one adopted by the writer when working from the main supply at 100 volts. A useful detail which may be mentioned is the following: If a battery of accumulators be at hand, as is generally the case where electricity is used for medical purposes, these may be connected in the circuit as though for charging. By this means the pressure of the accumulator cells is opposed to that of the mains, and the potential is correspondingly reduced; thus, if eight cells are connected in upon and 100-volt circuit, the pressure acting upon the coil becomes $100 - 16 = 84$ volts. This procedure has the further advantage of keeping the cells charged and ready for use in other ways for which they may be required. The coil may also be driven from the accumulators instead of from the mains when gentle working or low tubes make this an advantage.

A useful distributing-board for coils with motor breaks can be made as shown in Fig. 42. It consists of a wooden base about 9 inches long by 3 inches wide, with three wall-plugs fixed to it, and these are wired as shown. The motor circuit is directly connected across the mains. The coil circuit is connected indirectly, and is only closed when the third or resistance circuit is closed.

This can be led to a simple series resistance for purposes of regulation, or to an accumulator for reducing the pressure, as indicated in the previous paragraph. Small ivory name-plates below the sockets give a neat appearance. The plugs used should by preference be concentric, to avoid confusion of polarity.

The board may be fastened to the wall or to the table which carries the coil.

Regulation by Shunt-Resistances.—As the working of coils from pressures of 100 volts or higher involves additional wear and tear upon tubes and interrupters, a plan which permits of obtaining pressures of 20, or 30, or 40 volts from the mains has decided advantages. For occasional use, and for unskilled operators especially, this is a great convenience, and for pressures of supply of



[FIG. 42.—DIAGRAM OF DISTRIBUTING PLUGS FOR MOTOR-DRIVEN INTERRUPTER.

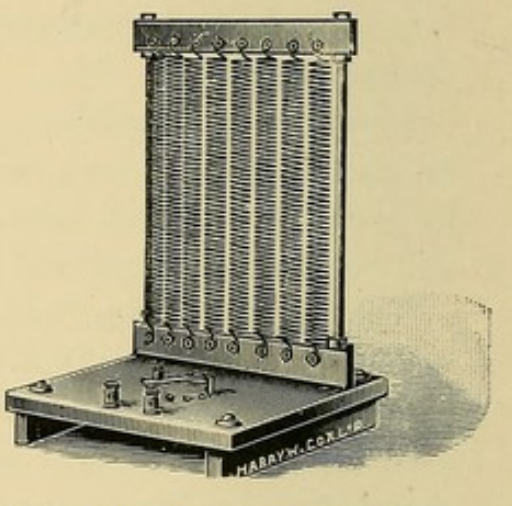


FIG. 43.—REGULATING RESISTANCE OF OPEN WIRE SPIRALS.

200 volts or upwards some means of reducing the pressures in the coil circuit becomes almost a necessity.

The ordinary way of using a resistance is to put it in series with the apparatus to be protected. The whole current then passes first through the resistance and then through the apparatus regulated, and for many purposes a simple resistance in series gives all the regulation that is wanted. Used in this way a resistance acts by choking down the current so that it cannot rise above a certain maximum. Resistances for regulation are usually variable, the changes being made by a crank arm, which can be moved by steps or gradations, and alters the amount of the resistance included in the circuit.

Another way of using resistances is to have them as a shunt or

bridge to the piece of apparatus, the current dividing and passing partly by the one channel and partly by the other. When two circuits are arranged in this way, in parallel, either of them is said to be 'in shunt' to the other, or 'shunted by' the other.

In shunt circuit regulation a steady flow of current along one of the two conducting paths is necessary, in order that the flow along this path, which may be called the regulating circuit, shall provide the gradual fall or slope of potential which is to be tapped for the other or utilization circuit. The resistance-wire in a shunt instrument forms a conducting-path joining the positive and negative mains, and its purpose is to provide a gradual fall or slope of potential along the length of the wire, the total fall on a 100-volt circuit being from 100 volts to zero. The difference of potential between any two points of the wire coils will be greater the further these points are removed from each other.

Thus in Fig. 44 the wire coils of the shunt circuit are composed of sixteen lengths of spirally-coiled wire. If the potential difference between the positive and negative wires of the source is 100 volts, the difference of potential existing between the two ends of each section will be one-sixteenth part of the total, and between the beginning and end of a double section one-eighth of the total, or, in the case under consideration, $12\frac{1}{2}$ volts, and thus the row of studs numbered from 1 to 8, which are connected to points on the resistance, provide places from which current can be drawn at any one of a series of intermediate voltages. When the crank arm stands on the stud numbered 1, the difference of potential between the terminals K, K, will be one-sixteenth of the total pressure supplied by the main, or a little over 6 volts, and when it stands at the fifth stud, as shown in the figure, the difference of potential between K and K will be 56 volts.

Shunt-circuit instruments for use with heavy currents are made as a rule of a number of open coils of thick iron wire affixed to the back of a slate or marble slab, with ample air-spaces for ventilation, by which means the heat generated in the coils is dissipated. The coils are joined together in a series, and at intervals a connection is led off to a stud on the front of the switch-board, whence the current is taken to the appropriate binding-screws through a moving crank arm, and according to the number, length, and thickness of the iron wire coils, the flow of the current through them may be 5, 10, 15 or 20 ampères as desired.

A red lamp is often fitted to the switch-board to indicate that the current is on through the coils. This is useful in order to prevent unnecessary waste. A voltmeter and ampèremeter and a safety-fuse are added, and in some cases an adjustable series resistance for further regulation in the utilization circuits is used to make the switch-board complete.

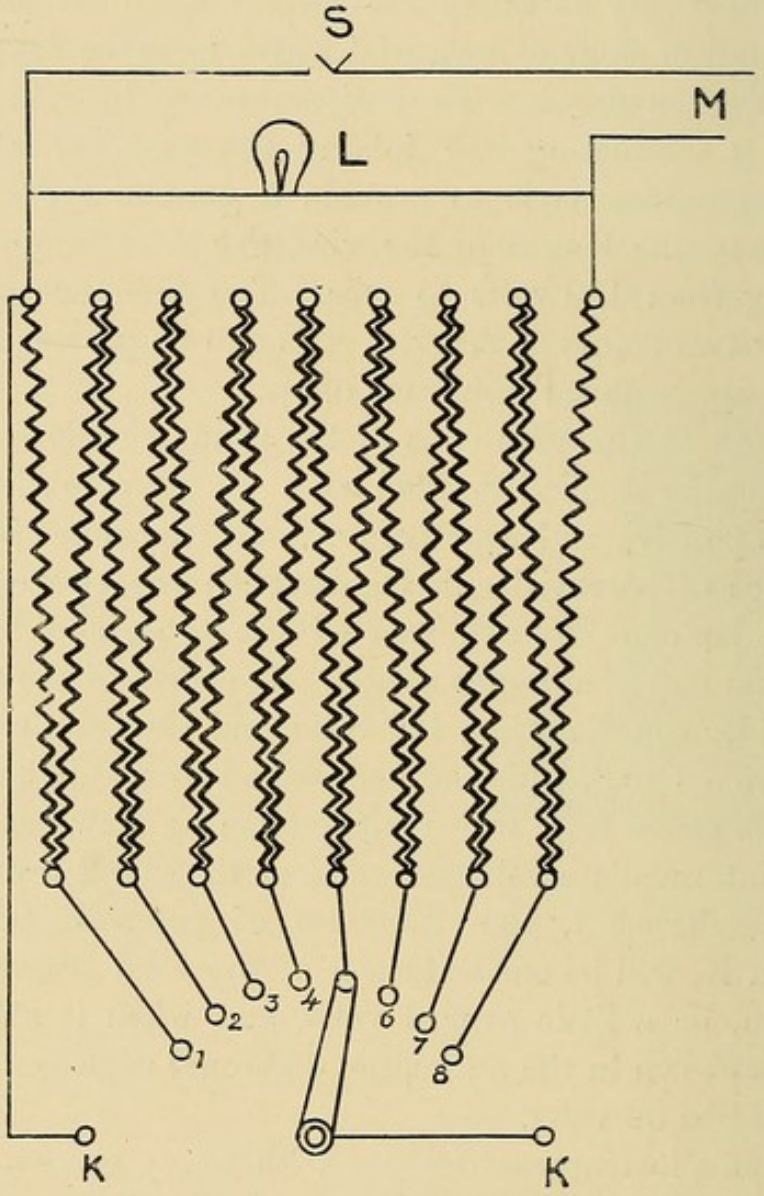


FIG. 44.—PLAN OF SHUNT-CIRCUIT RESISTANCE.

M, Mains. S, Switch. L, Pilot-lamp. K, K, Terminals for coil.

Figure 45 shows the general appearance of a shunt switch-board with two small adjustable series resistances added. One of these is in the coil circuit, the other is for the motor circuit. The motor is connected directly to the full pressure of the supply, the current for it being simply regulated by the series resistance only.

As long as the switch is closed, a large current passes through the shunt circuit and has to be paid for, although only a portion is being delivered by the utilization circuit to the coil. This is a considerable waste, and if large quantities of electricity were required, such rheostats would be extravagant. If the shunt carries 15 ampères

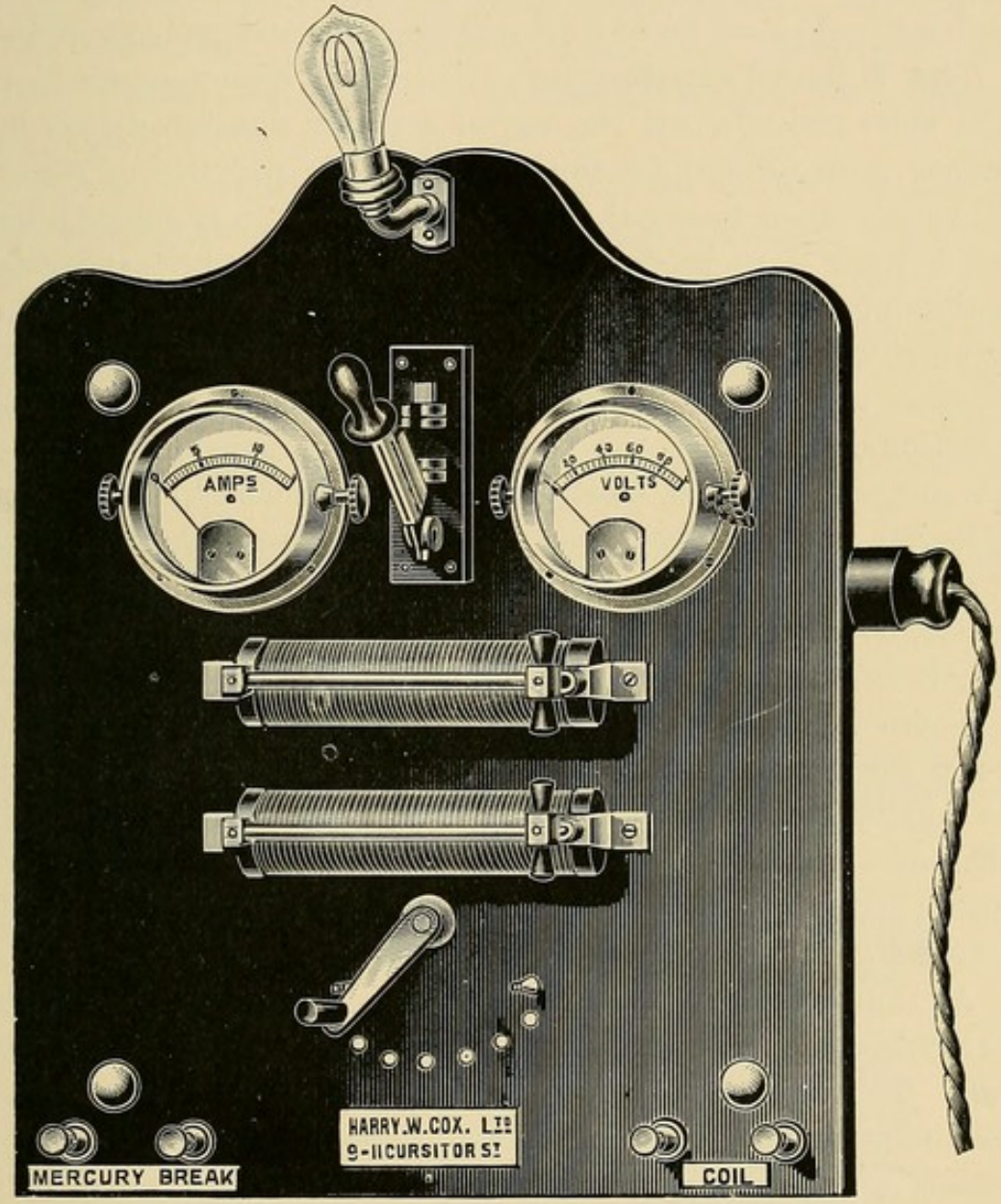


FIG. 45.—SHUNT RESISTANCE.

and is left connected with the main for one hour, the consumption of current with a 100-volt supply is one and a half units, and it is twice as much with a 200-volt supply. The price of the unit being 6d., the cost for using the apparatus for one hour on a 100-volt supply will be 9d., or less than 2d. for an *x*-ray application lasting ten minutes. As the resistance does not deteriorate, and requires

no time for cleaning and recharging, the saving of cost of renewals and the saving of time may be set off against this expense.

In consequence of the large current absorbed in a shunt resistance, it is necessary that the cables which connect it to the mains must be of a diameter which allows a current of 15 ampères (or more in some cases) to pass without heating them, and the fuses on such a circuit must be of correct dimensions and properly protected.

The Motor Transformer.—For extra high-pressure mains of 200 volts and upwards the use of a motor dynamo driven by the higher pressure and generating at a lower pressure of 40, 50, or 60 volts offers certain advantages, and should be preferred wherever much work is to be done, if skilled attention can be provided for maintaining the machine in order. Additional steadiness of supply is obtained if the field coils on the generating side of the motor dynamo are energized directly from the mains. Apart from the question of first cost, the use of the motor generator has decided advantages. In the electrical department at St. Bartholomew's Hospital this plan has been adopted, the motor generator being driven by the 200-volt mains, and supplying current at pressures which, by a simple regulation applied to the field magnets of the generator, can be made to range between 80 and 120 volts.

There is another mode of employing high-pressure mains for *x*-ray work which has considerable theoretical interest, and that is to employ condensers which are charged from the mains and discharged through the primary coil by means of a two-way commutator. This plan is now receiving study, and is likely to be introduced into practice in the near future.

An improvement upon this idea consists in the use of the current entering and charging the condensers to excite the primary of the coil. The advantage gained is that the charging current is non-oscillatory, while the discharging is oscillatory, and therefore less suitable. The discharge of the condensers is effected by a short-circuiting device. The Grisson Valve is an apparatus of this kind, in which the large capacity of the aluminium cell is utilized advantageously.

The Alternating Current Mains.—The direct application of the alternating mains to the excitation of coils is a more complicated matter.

If an induction-coil is connected to a source of alternating current through an interrupter, the discharge of the secondary is irregular

and is unfit for use with *x*-ray tubes. This would not be the case if the interrupter were in step with the periodicity of the current, and worked so as to break the circuit at the right moments. Attempts have been made to bring about this result, and several of the synchronous rectifiers described in the last chapter for use in the charging of accumulators from alternating mains can be adapted to work as synchronizing interrupters. Of these instruments the Siemens' rectifier and that of Mr. Russell Wright have proved capable of good work.

In all devices of the kind only one speed of interruption is possible, namely, the speed which keeps time with the periodicity of the supply. In this country this ranges for the most part between 40 and 100 periods per second, which is a satisfactory rate of interruption for an *x*-ray coil. Regulation of output can be easily effected in other ways, either by the use of series resistances to control the current, or by transformers to control the pressure.

A form of the mercury jet interrupter is made for use on alternate current circuits. It resembles the pattern used on direct circuits, except that the motor driving it must be a synchronous motor keeping step with the alternations. Fig. 46 shows its appearance, and the wheel seen in the illustration is a hand-wheel, which is used to speed up the interrupter. Such a manœuvre is usually necessary with synchronous motors, as they are generally unable to start from rest, and must be artificially assisted to reach their proper speed, though when once in step they maintain a constant rate even under trying variations of their load.

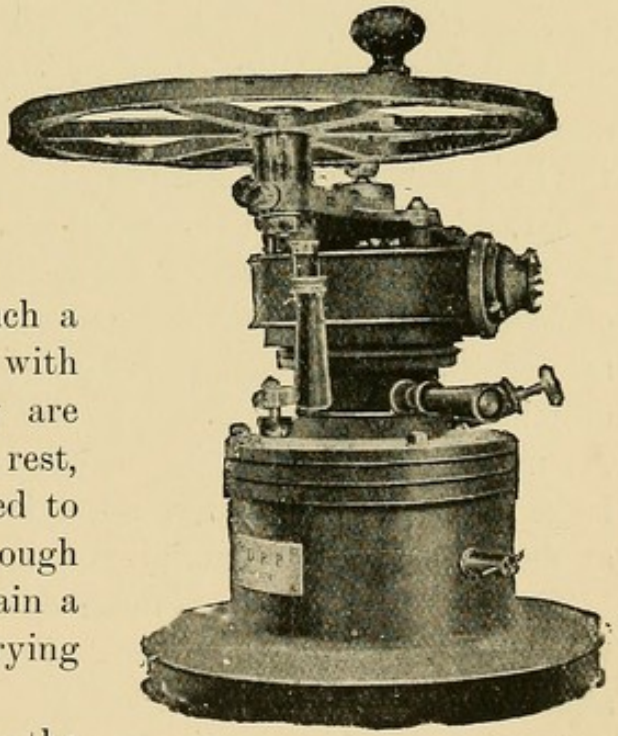


FIG. 46.—TURBINE BREAK, WITH SYNCHRONOUS MOTOR.

Another method of adapting the alternating current mains for the operation of coils in *x*-ray work is to use the aluminium rectifier described in the preceding chapter in one of its four-celled forms. Though the current given out by

this appliance is pulsatory rather than continuous, it has been of great value in the solution of the problem of the use of the alternating mains. A Pollak or a Nodon valve rectifier may be used as a source of current for *x*-ray work, both for driving a direct current motor to actuate the interrupter and for supplying the primary circuit of the coil. The rectified current may be regarded for *x*-ray purposes as the approximate equivalent of direct current, and the details laid down in the sections on direct currrent mains may be considered as applying equally well for all practical purposes to the rectified current of either of those valves.

The tendency of the Wehnelt interrupter to keep step with the pulsations of an alternate current points out another method of making use of the alternating mains. The form already described as the Gaiffe-Gallot interrupter (Fig. 29) works well on alternating current circuits at pressures of 100 volts.

With pressures up to 110 volts the ordinary forms of Wehnelt interrupter may be used if arranged in series with a single cell of the aluminium rectifier, and this can easily be constructed at home by anyone with a taste for mechanical work. It is possible that the simplification of the apparatus might be taken a step further by combining the rectifier and the Wehnelt break in one vessel. To do this the electrolyte of sulphuric acid should be replaced by one of ammonium phosphate, and an aluminium rod substituted for the lead plate forming the negative pole.

To make this device successful a large volume of electrolyte would be necessary, as the heat generated in an electrolytic interrupter is considerable, and the valve effect of the aluminium cell falls off at 40° C. It is not necessary to increase the surface of the aluminium rod in proportion to the increased volume of electrolyte. A surface of 10 square inches of aluminium is sufficient for fairly large currents, as the valve effect is best when the current density at the surface of the aluminium is moderately high.

The choice among these methods of employing alternating mains will depend upon the worker. For least expense, the use of the aluminium valve for charging accumulators, and the working of the coil from these with the Mackenzie Davidson interrupter, is preferable.

All the methods of utilizing alternating mains which have been enumerated are methods of adapting that type of current to direct current types of apparatus, and are of the nature of makeshift

contrivances. The natural way of utilizing alternating circuits would seem to lie in the direction of step-up transformers capable of providing the necessary voltage for an *x*-ray tube. This tempting

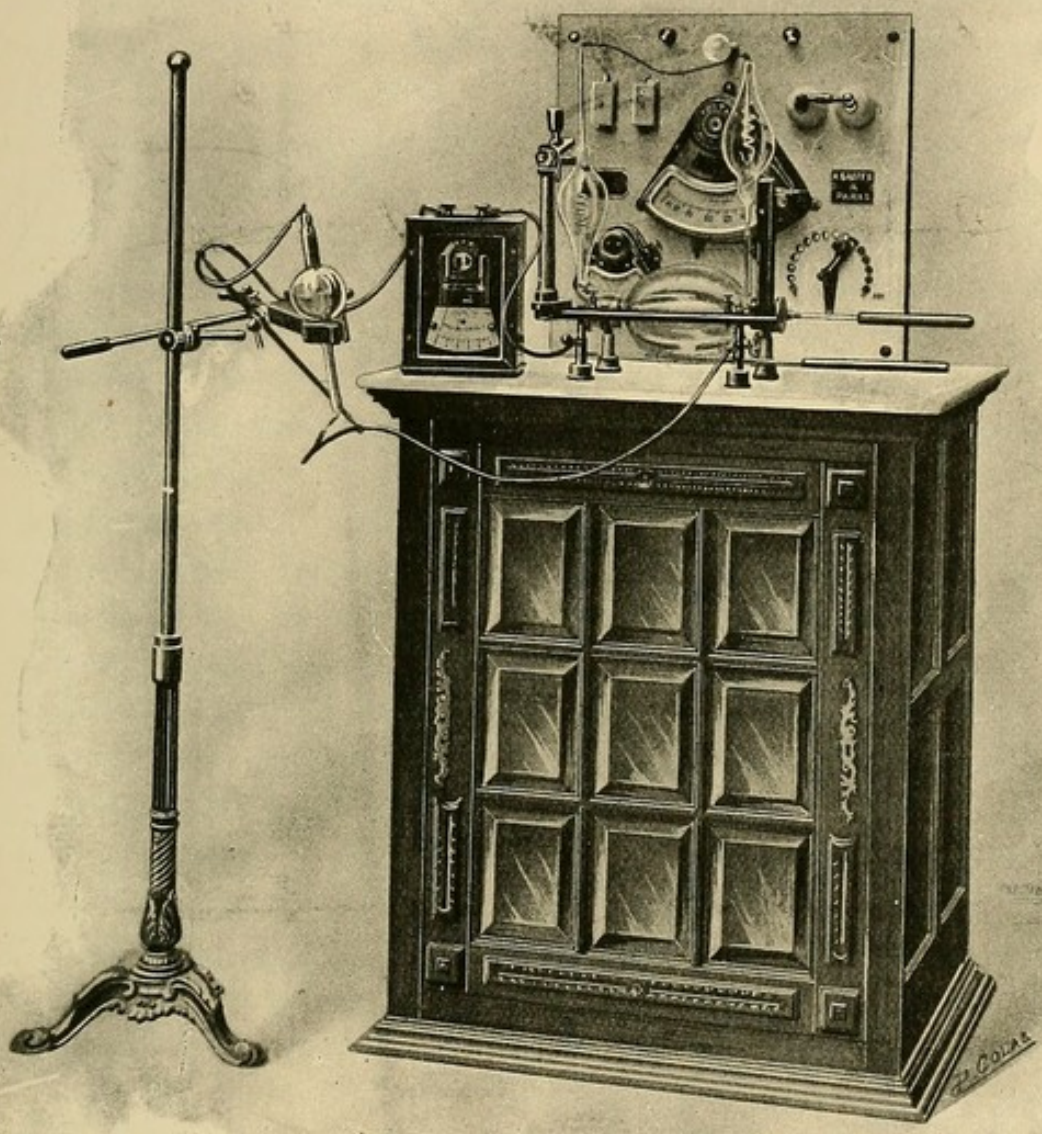


FIG. 47.—GAIFFE'S TRANSFORMER APPARATUS FOR X-RAYS (MEDICAL SUPPLY ASSOCIATION).

short-cut has attracted investigators since the time of the first discovery of *x*-rays, but the practical difficulties of the method have prevented the realization of the idea until quite recently. Villard, in 1899, had already advanced the matter very notably by his device

of a valve-tube, and by suggesting the employment of condensers of small capacity to limit the output of the transformer, and so to protect the tubes. Other obstacles of no small magnitude arose

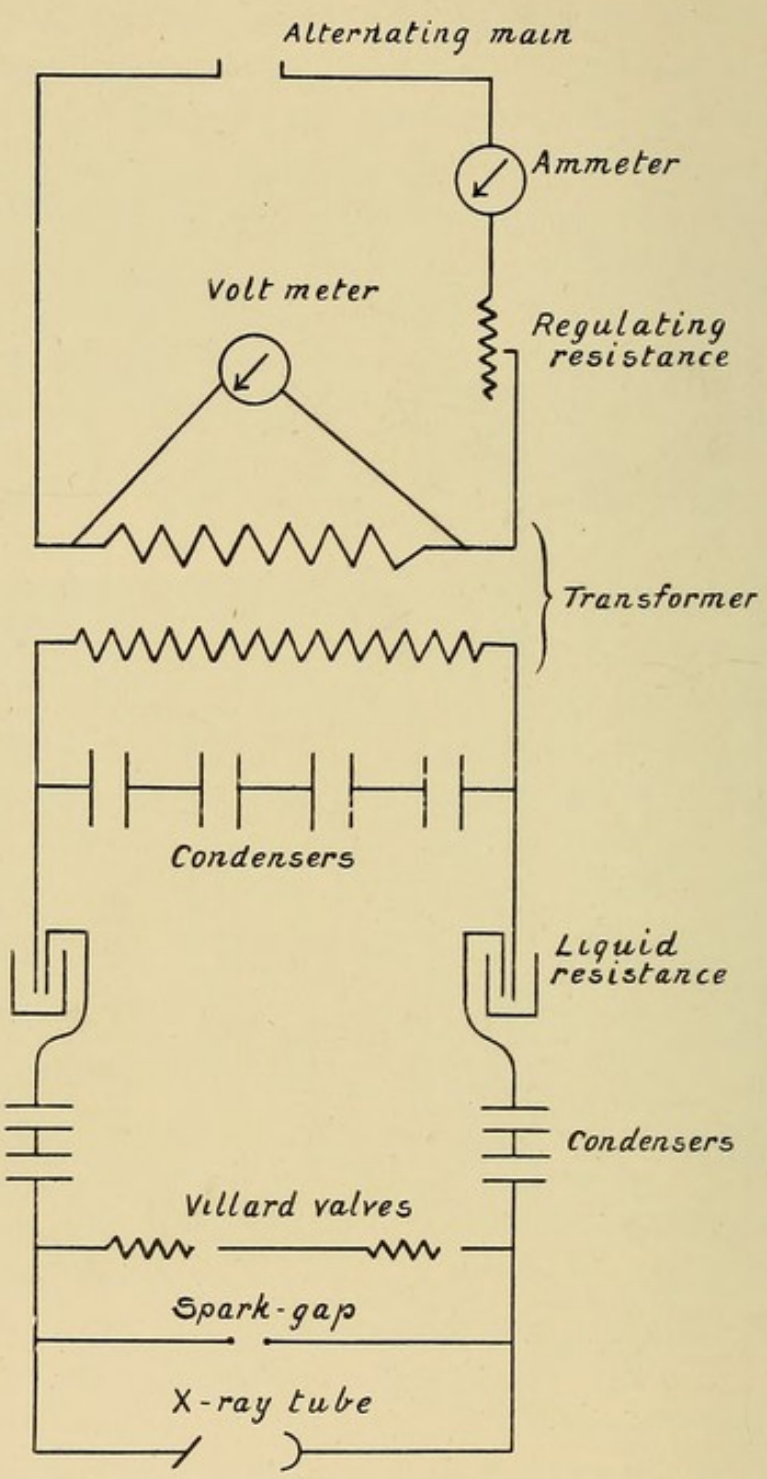


FIG. 48.—PLAN OF GAIFFE'S TRANSFORMER APPARATUS (AFTER BELOT).

from the very high electromotive force required for exciting x-ray tubes satisfactorily, and the difficulty of constructing a transformer capable of providing such a pressure without breaking down was for a time insuperable.

The experience gained in the manufacture of large coils during recent years has prepared the way for the successful construction of transformers capable of providing pressures of 60,000 volts, the pressure which is needed for *x*-ray work. Messrs. Gaiffe, of Paris, have developed the ideas of Villard, and by the use of ingenious safeguards have succeeded in evolving a group of apparatus for producing *x*-rays through the medium of a transformer which seems to fulfil requirements admirably. The whole of the apparatus is enclosed in a cabinet, and is arranged in such a way that the simple closure of a switch illuminates the *x*-ray tube with a perfectly steady illumination, the intensity of which can be varied by adjustment of a resistance in the exciting circuit of the transformer, while the current through the tube is unidirectional, and can be measured by a milliampèremeter of special construction, the inverse waves being shunted through a pair of Villard tubes.

The apparatus is so convenient in working that for places supplied by alternating current it is likely to displace the induction coil apparatus, and indeed it may come into use in places supplied by direct current because of its simplicity, especially when the direct current-supply is at a pressure of 200 volts and upwards, and is therefore somewhat inconveniently high for use with coils.

For application to direct current circuits a rotary converter must be added to the equipment to change the direct into alternating current before it enters the transformer.

The details of construction of the apparatus are shown in the annexed diagram (Fig. 48).

The alternating current mains supply the low-pressure side of the step-up transformer. Its high-pressure side is shunted by four condensers in series to one another, and these are called guard condensers. It is probable that this action may be partly protective and partly of the nature of a resonance device. Each lead then passes through a liquid resistance, and then to another pair of condensers. On the further sides of these condensers a pair of Villard tubes are arranged in series, so as to carry the current in one direction and resist its passage in the other. When they are in opposition the current passes through a galvanometer to the *x*-ray tube. A spark-gap is also arranged in parallel to the tube as a means of estimating its resistance.

Another way of getting rid of the semi-phases of current which are in the wrong direction, is the synchronously revolving commu-

tator which has been devised by Koch. It consists of a pair of rotating arms driven by a motor supplied by the alternating current which feeds the transformer, and it is so arranged that in its rotation it collects the appropriate impulses from the terminals of

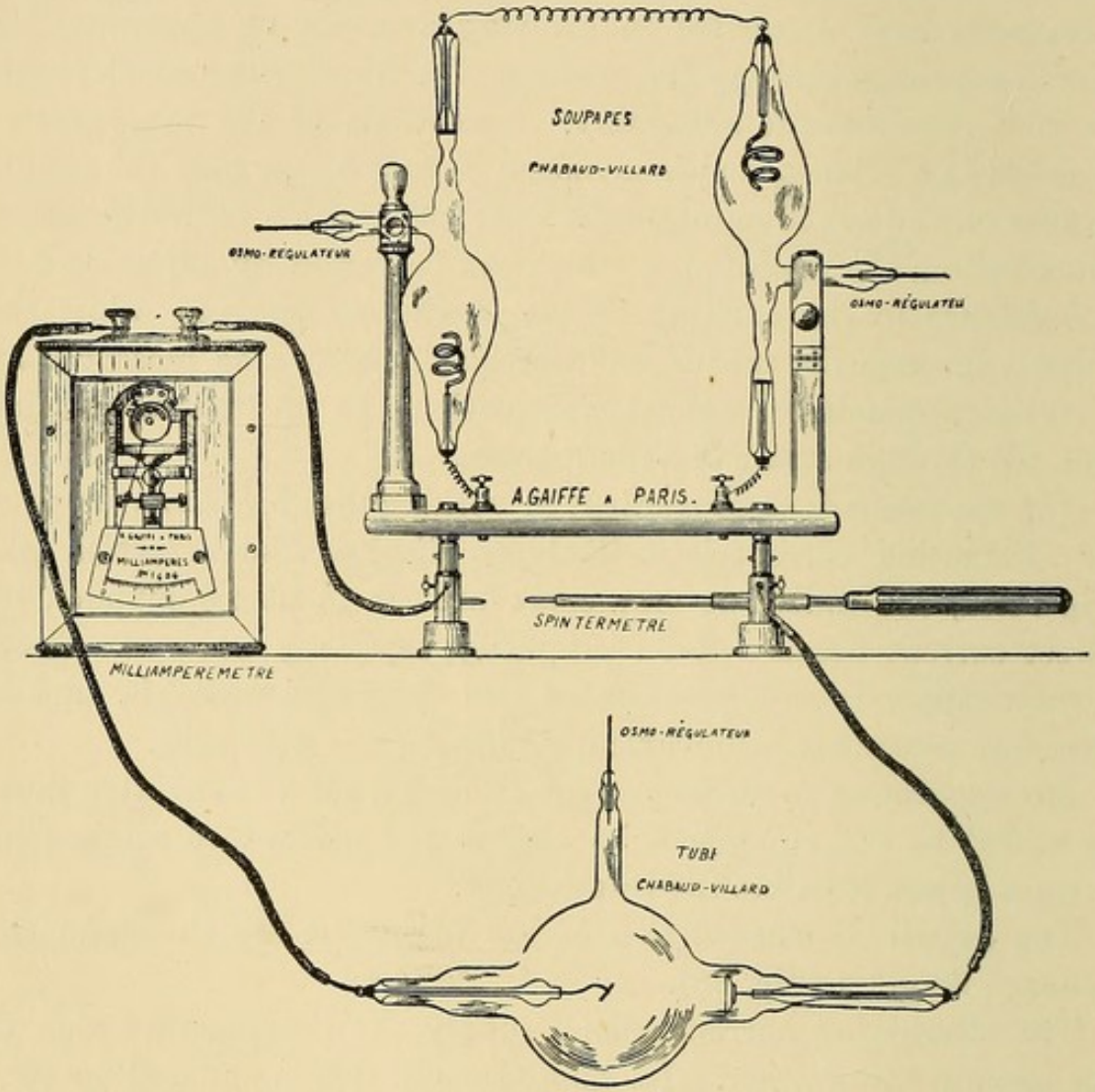


FIG. 49.—DETAILS OF GAIFFE'S APPARATUS, SHOWING THE DISPOSITION OF THE VALVE TUBES AND MILLIAMPÈREMETER (MEDICAL SUPPLY ASSOCIATION).

the high-potential transformer, and conveys them to the circuit of the *x*-ray tube. The appearance of a tube operated from this device is sharp and clear, and the method, like that of Gaiffe, will probably come into use in places supplied by alternating current mains.

CHAPTER VII

ACCESSORY APPARATUS

The fluorescent screen—Tube-holders—Couches for x-ray work—Galvanometers —Protective devices—Gloves—Tube-shields—Exposure meters.

The Fluorescent Screen.—This is a contrivance for producing with the x-rays an illumination which can be perceived by the eye, and it affords a means of judging of the quality and quantity of the radiations of an x-ray tube, and renders possible the direct inspection of bodies by means of x-rays without the intervention of a photographic process.

The principle upon which the fluorescent screen is based is the property possessed by x-rays of causing phosphorescence or fluorescence in certain chemical compounds. For the manufacture of screens a fluorescent body—that is to say, one which is luminous only during the continuance of the excitation—is better than a phosphorescent body in which the luminous effect is more or less persistent; and on this account the phosphorescent compounds calcium tungstate and zinc sulphide are not now used for screens, as with these bodies there is a persistence of the images or after-effect, which tends to blur the sharpness of what is seen upon the screen. Barium platinocyanide, the compound originally preferred by Professor Röntgen, is still the best compound known for practical use, and commercial fluorescent screens are coated with this material.

Potassium platinocyanide is also used, but does not keep so well, as the salt tends to effloresce, and then is no longer fluorescent. Good screens can also be made with uranium oxy-fluoride, but this preparation has not come into general use.

Fluorescent screens are made by spreading an even layer of finely-crystalline barium platinocyanide upon a flat support, thin card-

board or vellum being usually employed. Great care is necessary in their preparation. The crystals must be of uniform size, and should form a layer of uniform thickness. About four grains are sufficient to cover a square inch. A favourite method of manufacture is to mix the barium salt into an emulsion with collodion, amyl acetate and acetone, and to spread it in a liquid form upon the support, which is then left in a horizontal position until the mixture is dry.

Fluorescent screens are mounted in light wooden frames, and are backed with black paper. When new the surface should have a lively greenish-yellow colour. A sheet of transparent celluloid may be used to protect the surface from dust or finger-marks.

These screens should be exposed to light occasionally. The prolonged action of *x*-rays gradually causes a change in colour, through which the screens lose the greenish tinge which they have when new, and acquire an orange-brown tint, and in this condition their fluorescent powers are considerably lessened.

It would be of great advantage for *x*-ray work if some compound of the nature of a dye could be discovered which would fluoresce with *x*-rays. Fabrics dyed with such a material and woven into tightly-fitting garments would do away to a great extent with the distortions which are inevitable when shadows are projected upon a plane surface, such as a flat screen.

The fluorescent light emitted by the screen is also of a greenish-yellow hue, and is not of a high degree of brilliancy, and for work with the screen it is necessary to have the room perfectly dark. Some workers even enclose the *x*-ray tube in a black silk covering to exclude the light given out by its walls, and others have recommended the use of tubes coated with a dark-coloured varnish with the same object. As the retina becomes very much more sensitive after a few minutes' rest in darkness (according to Béclère, a period of rest in a dark room of twenty minutes' duration increases the sensibility of the retina 100 times), a short period may be usefully spent in the dark room as a preparation before commencing operations. When difficult cases are to be examined, this is a very great help, particularly in the day-time, though after nightfall it is less necessary, as the retina is then already partially prepared. The eyes of the young are much better able to discern faint appearances upon the fluorescent screen than are those of their elders.

In examining an object with the fluorescent screen, the latter

must be kept in close apposition with the object. If this is not attended to, the images will be less distinct, and will appear too large, because the pencil of rays emitted by the tube is of a divergent character. The nearer the object and screen are to the tube the greater will be the exaggeration of the size of the image, while very serious distortions are produced if the object examined be not in a plane parallel to that of the screen. These effects can be very well studied by the use of the screen, and much can be learned in this way which will prove of great value when the taking of *x*-ray photographs is being practised. The posing of the limb, so that it is in proper relationship to the tube and to the plate, plays a very important part in successful *x*-ray photography.

The value of the fluorescent screen in practical work lies in the ease of its application. By its means any region of the body can be examined from all sides, and that in a comparatively short time. Its indications will suffice for a large proportion of medical and surgical cases, particularly for those in which coarse injuries of bones or of joints are being investigated, and for most foreign bodies; also for examinations of the thorax in experienced hands. On the other hand, the screen image is not able to reveal so much of the fine detail as can be seen in a photograph, and for difficult work the latter will consequently be preferred. The action of the *x*-rays upon a photographic plate are cumulative, and thus it can collect during exposure, and can reveal, on development, a number of points which might escape notice in a screen examination. Moreover, the photograph gives a permanent record, and one which can be measured and can be studied by several independent observers.

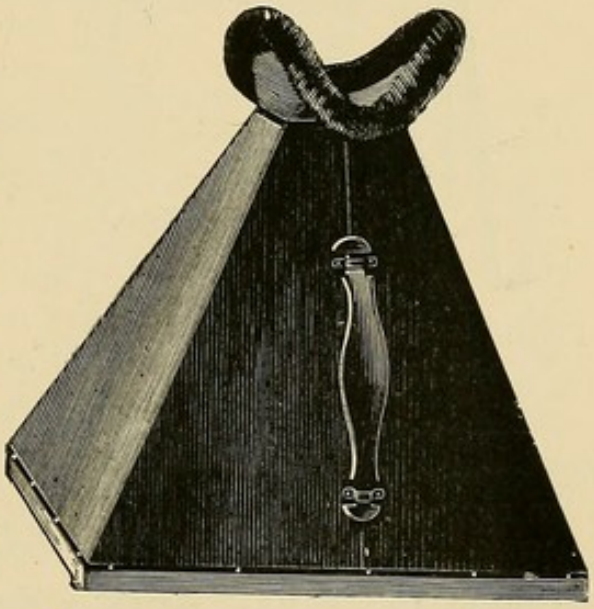


FIG. 50.—THE CRYPTOSCOPE (COX).

The cryptoscope or fluoroscope (Fig. 50) is an arrangement of the fluorescent screen designed to permit of examinations being made in a room which is not darkened. It consists of a camera or dark box, at one end of which

is a fluorescent screen, while the opposite end is provided with apertures for the eyes of the observer. The screen is thus viewed in darkness even in a lighted room.

The instrument is of no great practical value for diagnostic purposes, but is often useful for making a preliminary examination in order to verify the position of the patient and the working of the tube before making an exposure.

Tube-Stands.—A firm tube-holder on a steady base is an important accessory for *x*-ray work. Many forms of tube-stand have been devised, and may be seen illustrated in the instrument-makers' catalogues. The stand shown in Fig. 10 represents a very useful form. It has the advantage of being constructed of wood, of being stoutly built, and of being sufficiently tall for all purposes. The upper cross-bar serves to hold up the wires well away from the patient, who is thus less likely to come accidentally into contact with them. The stand is 5 feet high. The wires from the coil may be led directly to the ends of the upper cross-bar, or one may first be taken to a galvanometer and a valve tube, as shown in the drawing. Two other wires lead from the ends of the cross-arm to the terminals of the tube.

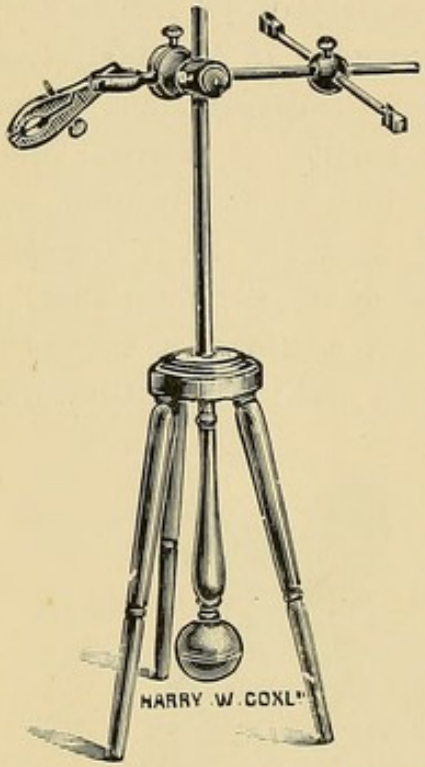


FIG. 51.—PORTABLE TUBE-STAND (COX).

Another useful and lighter stand is shown in Fig. 51. It is of wood, and carries a cross-arm for supporting the wires, and has a very good ball-and-socket attachment, which permits of great latitude in the placing of the tube. (See also Fig. 57.)

In some situations a tube-holder attached to the wall is useful, and Fig. 52 shows an ingenious holder for that purpose.

Couch for X-Ray Work.—Many forms of special couch have been devised for *x*-ray work. In most of them the tube is fixed beneath, and the examination is conducted with the patient in the recumbent position, while the screen or photographic plate is above.

For most screen examinations, except, perhaps, in simple inspections of the upper limb, it is a convenience to have the patient in

the horizontal position. The tube is fixed on a carriage, moving upon guides beneath the couch, so as to traverse in all directions

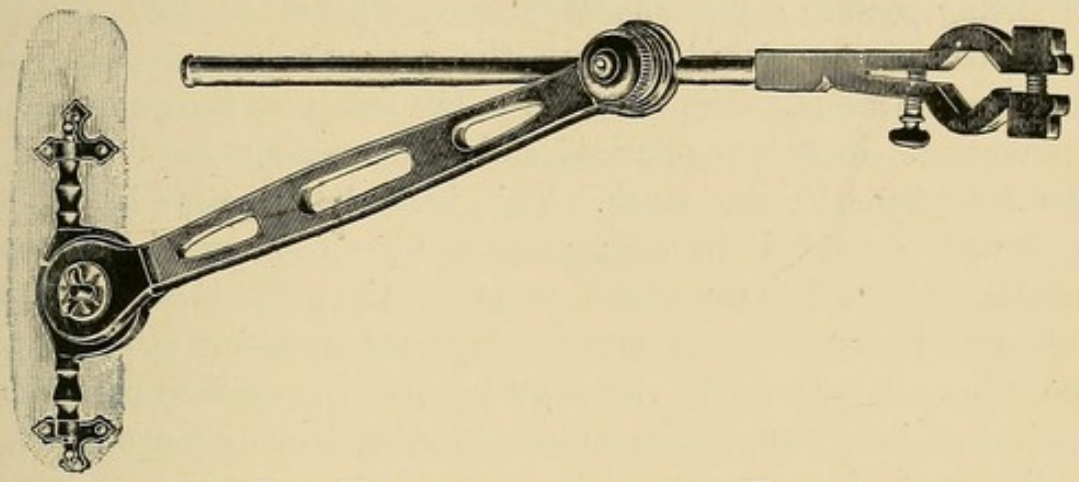


Fig. 52.—Tube-Holder for fixing to a Wall (Schall).

without interruption of the connecting wires, and the part of the couch upon which the patient lies is made of cotton or other

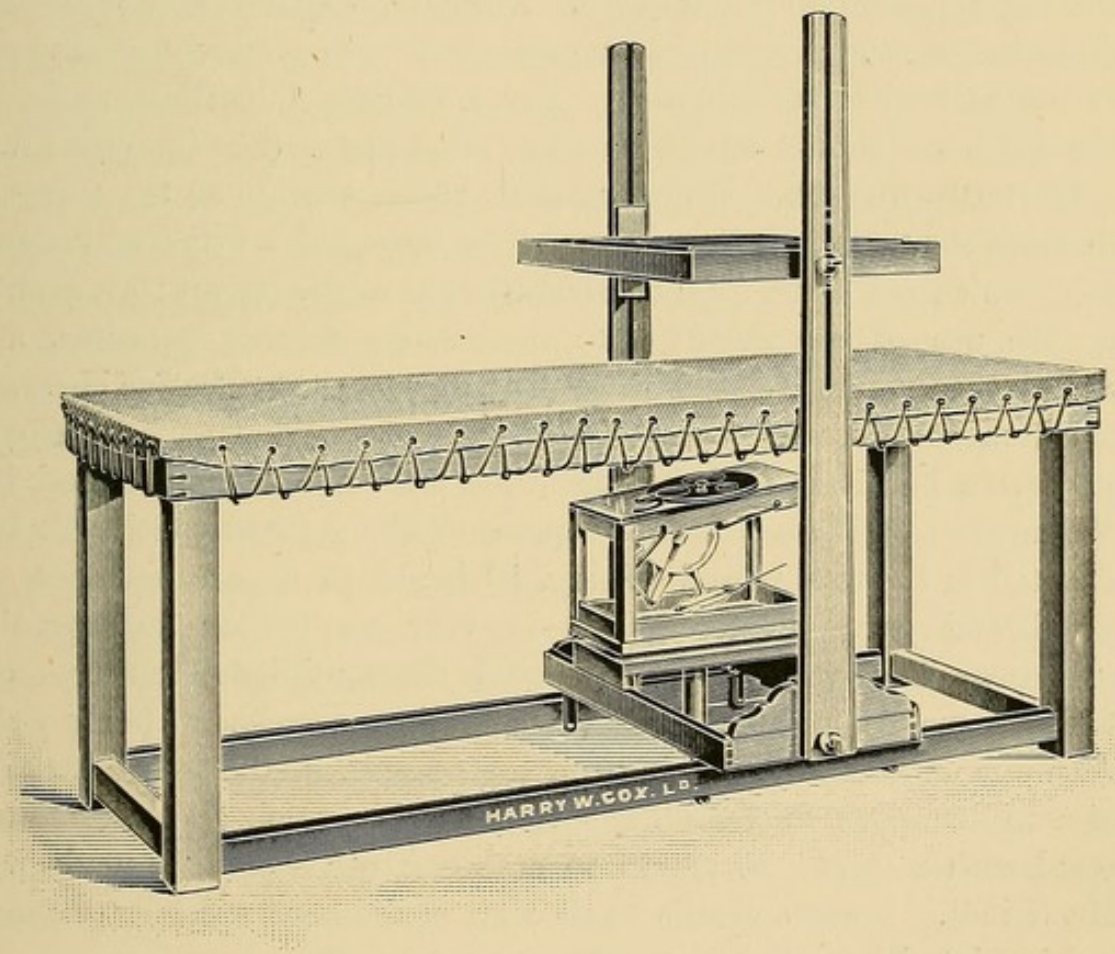


Fig. 53.—X-Ray Couch (Cox).

material transparent to *x*-rays. With a couch of this kind any part of the body can be inspected at will, and neither the patient nor

the operator need adopt the uncomfortable attitudes which are sometimes required for the examination of a patient in a standing or sitting posture. Fig. 53 shows an example of this kind of couch. A pillow may be placed beneath the patient's head to make him more comfortable. The carrier for the screen or the photographic plate can be displaced as desired, and its movements are followed by the tube beneath the couch. This, in its box, is seen below, and a screw is provided for giving to the tube a measured amount of displacement when the couch is being used for localization and stereoscopic work. The tube-carriage moves along rails, so that the tubes can be brought vertically beneath any desired part of the subject, and the plate-carrier and the tube-carrier both move together, so that they always preserve the same relative position.

For localization purposes, when the tube and plate are in the proper position, slide the tube-box 3 centimetres away and make an exposure. Then slide the box 6 centimetres towards you, and make another exposure on a new plate. After development and printing, the prints can be placed in a stereoscope to give a stereoscopic view of the part under examination. For cross-thread localization both the exposures should be made on the same plate. (See Chapter IX.)

Galvanometers.—Galvanometric measurements of the current through the *x*-ray tube can be made by means of a soft iron instrument which reads the total current passing in the circuit; or, again, by the use of a valve-tube to arrest the reverse impulses, an ordinary galvanometer can be used to measure the effective current in the right direction only. Both forms of instrument have their advocates, but it is probable that the magnetic instrument used in conjunction with a valve-tube represents the method which will be adopted in the future, and in Fig. 10 is shown an arrangement of stand and galvanometer which is very useful for therapeutic purposes. The writer has compared three milliampèremetres of different makes, and finds that their readings correspond fairly well with one another. A moving coil instrument, graduated in tenths of a milliampère to 3 milliampères, suffices. Such an instrument, fitted with a carrier to clamp to an *x*-ray tube-stand, is made by Mr. Schall. Messrs. Gaiffe* make an instrument specially wound and insulated for *x*-ray measurements.

Intensifying Screens.—Various attempts were made in the early days to increase the photographic effects of the *x*-rays and

* Medical Supply Association.

to shorten the long exposures which were then necessary for the taking of a photograph of the thicker parts of the body. With this object the 'intensifying screen' was devised. It consisted of a fluorescent screen, the surface of which was placed in contact with the sensitive plate, which thus received the direct effect of the *x*-rays, and in addition the luminous influence of the fluorescent screen. It has even been proposed to use two such screens, one on each side of the plate. The material generally used for these screens was tungstate of calcium; but it was found impossible altogether to avoid a mottled appearance or 'grain' upon the negative when these screens were used. In consequence of the improvement in coils and tubes these screens have become unnecessary, and are not used nowadays.

X-Ray Cabinets.—The apparatus necessary for *x*-ray work may be assembled together in a cabinet or cupboard with great advantage, particularly when the room in which the *x*-ray work is done is also required for other purposes. Most makers of *x*-ray apparatus can supply cabinets of the kind required, and an inspection of their catalogues is recommended to any intending purchaser. Fig. 54 indicates the type referred to. In it the coil is seen on a lower shelf or deck, while the sparking terminals and the mercury interrupter are above, and over this, again, there are cupboards for the reception of spare tubes and other accessories.

A less ambitious apparatus consists of a strong table or trolly on castors, with a lower shelf for the reception of the accumulators or the interrupters, and an upper one for the coil. Three shelves may be provided with advantage in some cases, and when most of the work will be done with a tube under a couch, the coil can be conveniently placed on one of the lower levels.

It is always an advantage to be able to bring the coil close to the tube, as this obviates the need for long lengths of secondary wire. These are awkward in a dark room, both because patients or visitors may come into accidental contact with them, and because they are apt to come into sparking distance of each other when the tube and tube-stand are moved about for purposes of adjustment.

If a fixed position be preferred for the coil, a convenient way of arranging the secondary wires is by means of overhead suspension, bringing them down to the ends of a cross-arm fixed to the upper part of the tube-stand (see Fig. 10). The wires from the ends

of the cross-arms to the tube itself are then independent of the rest of the circuit, and if wound in spirals they will have sufficient elasticity to allow of all likely displacements of the tube, and will preserve their symmetry for a considerable time.

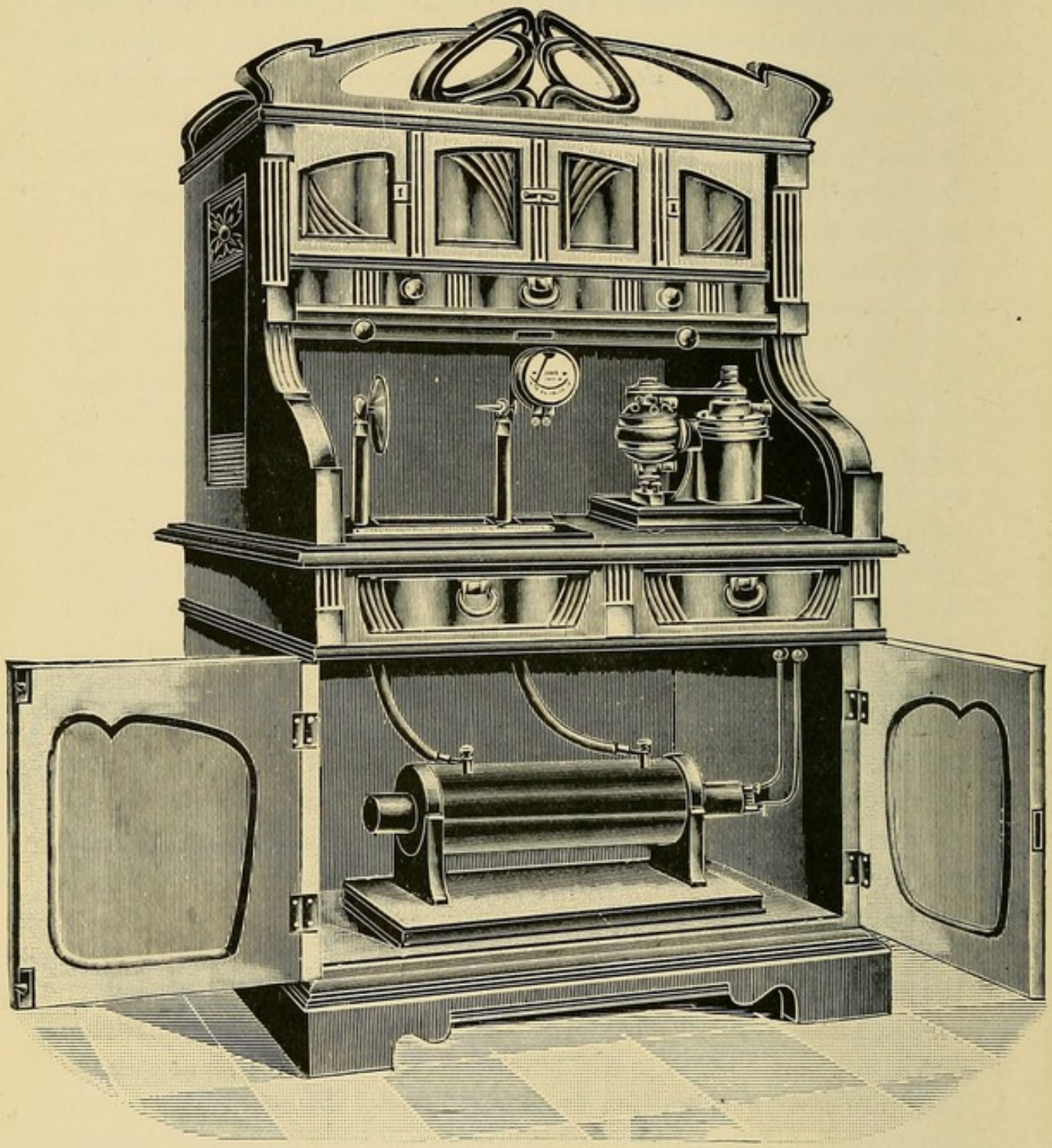


Fig. 54.—X-Ray Cabinet (Sanitas Company).

It may be more convenient to have the coil on a movable trolley, and to connect to the mains by means of a cord with counter-weight suspended from the ceiling, just as is done in the case of electric lighting pendants. The cord may then terminate in a

lamp-socket, which can be slipped on to a plug fixed on the trolley or on the base board of the coil. If a shunt-circuit resistance be used to lower the pressure of supply, this can occupy a place on one of the adjoining walls. The interrupter may be given a place either on the trolley itself or upon a shelf in a convenient corner of the room; electrolytic interrupters may even be placed in a distant room or cellar, as they need very little attention. By this device one can enjoy the advantage of noiselessness when doing *x*-ray work.

Protecting Devices. — The risk of producing injury by

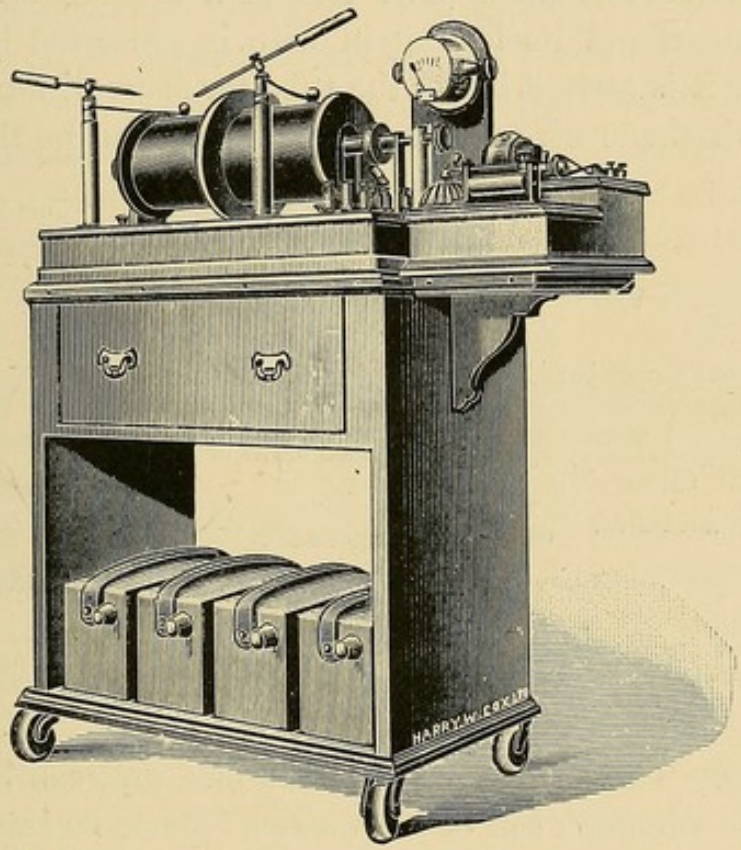


FIG. 55.—X-RAY TROLLEY FOR WARD USE (COX).

exposures to *x*-rays has led to the introduction of various protecting devices. Two separate conditions of danger must be guarded against: one is the risk of acute dermatitis in the patient, and the other is the risk of chronic dermatitis and other troubles in the operator.

Formerly, when *x*-rays were used for therapeutic purposes it was customary to cover the healthy parts around the affected region by means of a sheet of thin lead in which a hole had been cut of a size and shape to suit the part under treatment. Then if dermatitis were set up by the treatment its extent was limited by the size

of the opening in the leaden screen. Subsequently the use of special therapeutic tubes was recommended, and as lead-glass is comparatively opaque to x-rays, the tubes were constructed of this material, and were provided with a 'window' of thin soda-glass at the end of a special prolongation or side-tube. Thus the emission of x-rays from the tube was limited to a small area corresponding to the area of the soda-glass window.

Other special forms of tube which may be mentioned here are those designed for use within the cavities of the body, and particularly within the mouth for dental purposes. In these tubes the anti-kathode is at the slender end of a cylindrical or pear-shaped prolongation, and its leading-in wire is protected by a thick glass sleeve, or it is carried inside the tube for some distance. For safety the anti-kathode wire is earthed, as must also be the anode of the

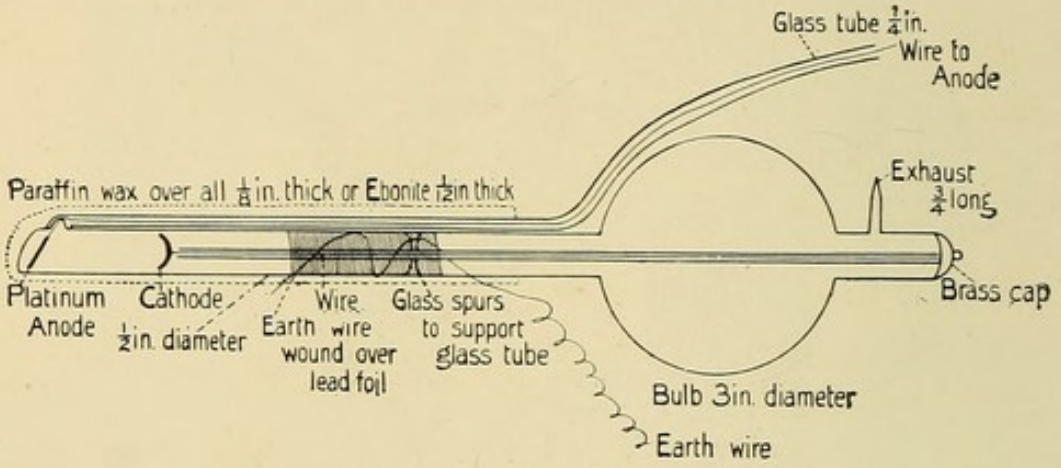


FIG. 56.—DENTAL X-RAY TUBE.

generator. These tubes are of small size, and can best be operated from a 2-inch spark coil or from a small static machine. For dental work various patterns have been devised, and the reader should refer to the papers of Mr. C. A. Clark* for further details of this interesting branch of x-ray work. For the accompanying illustration (Fig. 56) of one of Mr. Clark's tubes the writer is indebted to the Odontological Society of Great Britain.

The subject of special tubes for internal use is also discussed very fully by Dr. Bouchacourt in the 'Traité de Radiologie Médicale.'†

* 'A New Dental x-Ray tube:' *Archives of Röntgen Ray*, June, 1903; *Medical Electrology and Radiology*, 1903, p. 201; *Transactions of the Odontological Society of Great Britain*, April, 1903, p. 171.

† Paris, 1904, p. 606.

Tube-Shields.—In order to protect both operator and patient, Mackenzie Davidson and Williams buried their tubes in boxes of white-lead powder, leaving an opening on the side opposite the anti-kathode through which a cone of *x*-rays could emerge.

At the present time the same result is obtained by a cup-shaped shield made of thick glass, or of some composition which is opaque to *x*-rays, and many varieties of tube-shield of this type can now be bought. A tube-shield should not be so heavy as to be unsuitable for use with the tube-holders in ordinary use. It is almost impossible to find a suitable material which is absolutely opaque to *x*-rays. Even metal is not absolutely opaque, for *x*-ray photographs have been taken of pistol barrels showing the bullet within the bore, and it is better to be content with a moderate degree of partial opacity to *x*-rays, if in that way a shield can be obtained which is light enough to be carried comfortably by an ordinary tube-holder.

Fig. 57 shows a very good form of tube-shield made of a dense compound of indiarubber. The illustration explains its shape, and the mode of attachment to the *x*-ray tube, and a series of glass nozzles and diaphragms with variously-sized openings which can be adapted to it, when it is desired to limit the action of the *x*-rays to a very small area.

Gloves and other Devices.—As the parts which suffer most from the chronic dermatitis of operators are the backs of the hands, gloves can be used to serve as a protection. Steel gauntlets* or heavy indiarubber gloves† can now be procured, and something of the kind should always be worn to guard against the insidious development of that most serious trouble, chronic *x*-ray dermatitis.

Other protective devices for the operator which may be mentioned consist in the provision of metallic shields or guards at the sides of fluorescent screens to protect the hands during screen examinations, as this branch of *x*-ray work has been found to be a fruitful cause of dermatitis. The warming of high-resistance tubes with a spirit-lamp when in action on the coil has also led to the production of dermatitis in many cases, and spirit-lamps with long ebonite handles are now made to obviate this risk. Aprons of heavy rubber should be worn by operators who spend much time near *x*-ray tubes.

Focussing Diaphragms.—The sharpness of a photograph of

* Messrs. Gent of Leicester.

† Watson and Sons, High Holborn.

the thicker parts of the body may often be increased by the use of a diaphragm of metal or of thick glass between the tube and the patient. The best form which the diaphragm can take is that of a

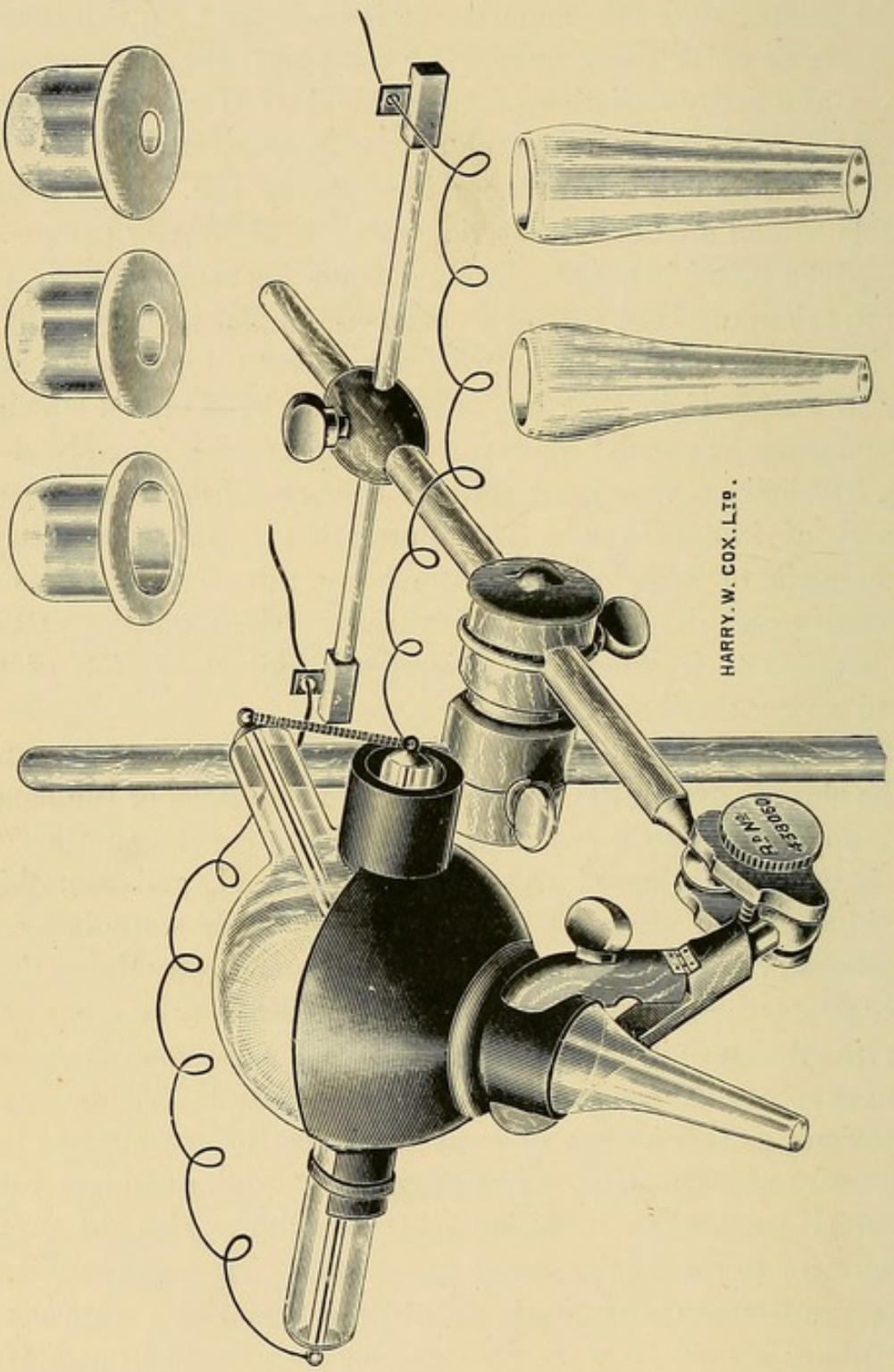


Fig. 57.—Tube-Shield and Tube-Holder.

short tube of lead or heavy glass, as this has a better effect than a disc in sharpening the image. The tube-shield shown in Fig. 57 acts very well in improving the focus of *x*-ray photographs.

Lamps for Negatives.—For the examination or the exhibition of 'negatives' a lantern illuminated by artificial light is most generally convenient. The simplest form resembles an ordinary dark-room lamp in which the negative is inserted in the place of the pane of ruby glass. The effect is improved if a sheet of plain ground glass is placed behind the negative, and if the negatives are very thin a sheet of opal glass is even better. Such a lantern made of japanned tin, with a semi-cylindrical back, and painted white inside, can be made very cheaply by a tinsmith to take the size of negative most commonly made use of. An electric lamp affords the best means of illuminating it.

Elaborate lanterns made in cabinet work for the illumination of *x*-ray negatives are figured by the instrument-makers, but as they cost from three to five pounds they are rarely seen in practical use.

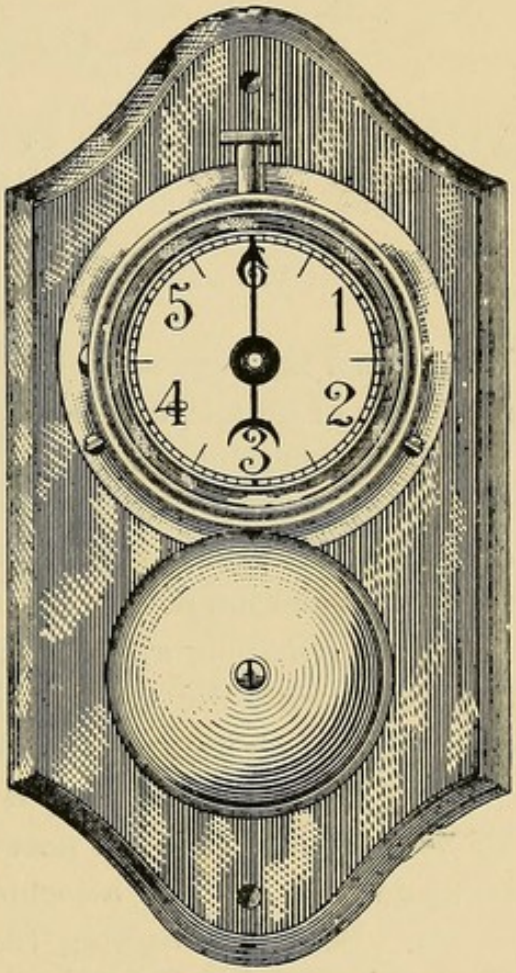


FIG. 58.—TIME-KEEPER FOR X-RAY EXPOSURES.

Time Measurements. — In treatment by *x*-rays the duration of the application is an important point, and the accompanying figure (Fig. 58) shows a simple and inexpensive time-keeper for this purpose. It is started by pressing the button, and goes for six minutes; it then rings a bell and stops.

Sand-glasses or stop-watches may also be used, but this little instrument seems particularly suitable for *x*-ray purposes, as fractions of the time are indicated by the movement of the hand round the dial. It is made by Messrs. Vandome, Titford and Co., 56, Leadenhall Street, E.C., and costs seven shillings and sixpence.

CHAPTER VIII

THE PRACTICAL WORKING OF THE X-RAY APPARATUS

The coil—The tube—Screen-work—Photography.

THE proper management of Röntgen-ray work involves attention to a number of details, and demands careful study and long practice. Without experience, the operator may produce nothing but poor results, even with the best and most costly coil. In the present chapter an account is given of the elementary procedures necessary for the acquisition of familiarity with the apparatus, the case being treated in a manner appropriate to a beginner who has acquired a coil fitted with the ordinary hammer break, and driven by six or eight cells of an accumulator battery.

The Coil.—The first step is to connect the coil with the battery. To do this, two wires are necessary, and the coil attachments must be made first and the attachments to the battery terminals afterwards. Before connecting the latter, be sure that the switch on the coil is not closed. This switch, which is sometimes called the 'commutator,' or 'current reverser,' fulfils a dual purpose; when the switch handle is standing upright, as shown in the further left-hand corner of Fig. 11, it interrupts the primary circuit, and prevents the current from passing from the battery to the coil; when turned down to the right, it allows the current to pass in one direction through the primary circuit, and when turned down to the left, it reverses the current and allows it to pass in the opposite direction. The usual form of commutator here figured was devised by Ruhmkorff.

The tension-screw (B) of the hammer should be turned to the right in order to reduce the pressure between the spring (D) and

the contact-screw (C), so that the contacts touch each other lightly. When this is the case the hammer can move easily, and will begin to vibrate when a small current is flowing. The face of the hammer should be close to the end of the core. A distance of $\frac{1}{10}$ inch is suitable. The handle of the switch may now be turned to the horizontal position to close the circuit, the hammer will begin to vibrate, and sparks will commence to pass between the discharging-points of the secondary coil, if these have been set beforehand to a distance apart of 2 or 3 inches. The discharging points may next be separated to see what length of spark the coil is giving. If necessary, the pressure at the platinum points can be increased by means of the tension-screw until the sparks passing between the discharging-points are 4, 5, or 6 inches long. The battery and coil are then in working order and ready for use, and the current may be turned off by means of the switch. The latter should move stiffly, otherwise an accidental movement might set the coil in operation at an awkward moment, communicating a shock to the operator or to any other person who might be in contact with some part of the circuit. When working alone it is prudent to insert a visiting-card between the contacts of the commutator when it is turned off, as this obviates the risk of turning on the current by accidental movements. The coat-sleeve, for stance, may brush against the handle of the commutator and turn on the current at an awkward moment.

The Tube.—The *x*-ray tube is now fixed in its holder and connected by two pieces of fine gutta-percha covered copper wire to the supports of the discharging-rods.

The wires leading from the coil to the focus tube should not be so near to each other at any part of their course that the sparks can pass between them instead of through the tube. The wires in their course to the tubes should not run very obliquely, or one of them may lie too close to the bulb of the tube, and a spark may pass at that point and puncture the glass. Caution is also required to avoid shocks, both from the coil and from the wires leading to the tube. The operator should make a rule never to touch any part of the apparatus while the current is on. If any readjustment be required, the current should always be switched off for the required alteration to be made. The current from a single wire can give a smart shock, and even though not dangerous, it may startle the operator, and cause him to upset the stand or break the tube; but if any part of

the body form a part of the secondary circuit, by contact with both wires at the same time, the consequences might be serious.

Too great care, therefore, cannot be taken to prevent the current entering the body either of the operator or of his patient; the larger the coil used the greater are the precautions necessary. The focus-tube should be fastened in the holder so that the anti-kathode faces the photographic plate or screen, and all wire attachments must be secure.

To ascertain the direction of the current, the appearance of the tube in action is taken as a guide. If when the switch is turned on the tube show an even hemisphere of green fluorescence on the side facing the front of the anti-kathode, then the current is in the right direction; but if the green light be patchy and irregular, the direction is probably wrong. In case of doubt reverse the switch, and if all be correct the wall of the tube between the anode and kathode should fluoresce evenly with a characteristic apple-green colour. By the use of the fluorescent screen all doubt may be set at rest; for when brought up to a tube through which the current is passing in the right direction it will be illuminated brightly, and the hand placed behind the screen will show the shadow of the bones distinctly. If the direction of the current be wrong scarcely any Röntgen rays will be produced, so that only a feeble fluorescence of the screen can be perceived.

Having once found the right direction, make a mental note of the arrangement of the primary wires, and note also the direction of the handle of the switch. Change the wires of the battery to the opposite binding-screws, and the direction of the current is altered; change the direction of the switch-handle to the opposite side, and the direction of the current is again altered; change both again, and the current flows in the same direction as at first.

If the anti-kathode should become red-hot when the tube is in action, the current used is too great, and should be lessened by reducing the pressure at the platinum points by means of the tension-screw. The tube is in good working condition when a small part of the surface of the anti-kathode shows just a faint redness.

When experience has been gained in the use of the hammer-break, it will be easy to proceed to the employment of mechanical or electrolytic interrupters. The sections in which these have been described should be read over afresh before making a start with

any of these appliances. Experience with the hammer-break will teach the beginners many little details of procedure, and will enable him to acquire a familiarity with the behaviour of induction coils, and with the defects of the hammer-break. It may be said that with the mechanical interrupters the coil works much more effectively, and at the same time much more smoothly than with the hammer.

When the coil and the tube are working satisfactorily the room should be darkened, and the fluorescent screen should be brought into use. The hand should be held flat against the back of the screen, and both should be approached to the front or fluorescent hemisphere of the tube. The bones will then be seen, and a few experiments should be made to note the peculiar effects of distortion which become evident if the wrist and fingers are twisted into irregular and oblique positions away from actual contact with the back of the screen. By using different tubes the variations in the density of the shadows of the bones can be noted, and this variation should be compared with the resistance of the tube, as determined by measurements of the alternative spark-length at the discharging terminals of the coil.

The normal articulations may all be carefully examined in turn and studied from various points of view in order that a familiarity with their ordinary appearances may be acquired.

The operator must refrain from examining his own hand too frequently, as by doing so he is very likely to prepare the way for chronic dermatitis, a condition which is of extreme gravity. In screen-work there is a tendency to approach the object nearer and nearer to the tube for the sake of the extra illumination which is gained from proximity to the source of x-rays, and this is favourable to the production of dermatitis. Moreover, an interested observer may easily spend many minutes in examining the effects shown by the screen, and may forget that there is a danger of setting up acute dermatitis if any one part be kept close to the tube for any length of time.

The Photographic Exposure. — An x-ray photograph may next be tried. For this a plate is taken from its box and transferred to an opaque paper envelope in a dark room. These envelopes are supplied by the instrument-makers in proper sizes, and are largely used. More elaborate plate-holders of wood can also be used if preferred. After exposure, the plate still in the envelopes is taken back

for development to the dark room. Where light-tight envelopes are used it is well to adopt a routine of placing the sensitive surface of the plate beneath the plain or 'address' side of the envelope.

To make an exposure, the protected plate is laid upon a flat surface, and the hand or arm of the subject is placed upon it. The current is turned on, the subject keeping quite still during the exposure, which need not last many seconds; the plate is then developed in the usual way.

Different parts of the body require different periods of exposure, because of their different thickness.

The average exposures with a 12-inch coil are as follows: A, with platinum break and 16 volts from accumulators; B, with mercury-set interrupter and 80 volts from mains on coil. Distance, 18 inches.

	A.	B.
Hand, Wrist	15 to 25 seconds	5 to 10 seconds.
Forearm, Elbow, Arm	25 to 35 seconds	10 to 20 seconds.
Shoulder	1 minute	20 to 30 seconds.
Thorax	1 minute	20 to 30 seconds.
Foot, Ankle	30 to 40 seconds	15 to 20 seconds.
Knee	40 to 60 seconds	about 25 seconds.
Leg	35 to 40 seconds	about 20 seconds.
Thigh	50 to 60 seconds	20 to 30 seconds.
Hip	1 to 1½ minutes	30 to 35 seconds.
Pelvis	1 to 2 minutes	30 to 45 seconds.
Abdomen	1 to 2 minutes	35 to 40 seconds.
Head	1 minute	30 seconds.

These exposures are those found by experiment to be correct for imperial flash-light plates. If Lumière *x*-ray plates are used the exposures may be shortened. For example, a good negative of the abdomen may be obtained in thirty seconds with the latter make of plate.*

With the electrolytic interrupter the exposures may be reduced even further—say by one-half.

The distance of the tube from the object to be photographed is

* For this table the writer is indebted to Dr. Orton, Clinical Assistant in the Electrical Department of St. Bartholomew's Hospital.

important. The length of the exposure will vary according to the distance, the penetrating power of the tube, and the thickness and opacity of the object. It need scarcely be urged upon the beginner that he should practise with his own apparatus in order to learn the methods by which the best results are to be obtained before taking photographs of patients. He will find in his own person, or in that of an interested friend, a convenient subject for experiment. When he has succeeded in taking every part of his own body, he will be prepared for the ordinary difficulties of Röntgen ray photography.

Although the clothing is practically transparent to *x*-rays, yet it is desirable, when taking a Röntgen photograph through a thick part of the body, as the thigh or hip, the trunk or the pelvis, to remove superfluous clothes, as they offer some resistance to the rays, both by their material and by their dyes, and especially because buttons or hooks and eyes or pins in the clothing will leave their impressions on the plate, and may thus obscure the result.

It is in the photography of thick parts of the body that difficulties are met with. The chief of these is due to want of definition, but distortion of the images must also be reckoned with. One often finds, instead of a sharp image on the plate, that there is only a vague blackening, with little or no detail, a result which is due mainly to the phenomenon of diffusion and the action of secondary rays. The effect of diffusion is to blur the image, just as happens with ordinary light when an object is viewed through a turbid or foggy medium. Professor Röntgen showed that bodies in general behave towards the rays as turbid media do to light; he also showed that secondary rays were produced by the rays when they impinged upon solid bodies, and that even the air traversed by *x*-rays becomes a subsidiary source of other irregular *x*-rays, which, though feeble, are sufficient to blacken a sensitive plate during a long exposure. Mr. Wimshurst has also shown that photographic blackening of sensitive plates occurs in the whole region of space round a tube in action, and that the effect can be noticed even in plates which are fully screened by dense masses of metal from any direct incidence of rays from the anti-kathode of the tube. One main cause of the want of sharpness in *x*-ray photographs is the irregular *x*-ray radiation produced at various parts of the walls of the tube by waves of current coming from the coil in the wrong direction. A lead screen or diaphragm close to the tube has already been referred to as a means of sharpening definition by allowing a passage

to the rays from the anti-kathode, while stopping many of those emitted by the walls of the tube. But this does not, of course, do away with the diffusion of the rays in their passage through the subject to act upon the plate. A dense backing of thick glass or of lead applied to the photographic plate, on its reverse side, has also been found of use in 'sharpening' *x*-ray pictures of deep-seated parts, and it acts probably by absorbing the radiations which have penetrated the plate, and which might set up 'secondary' rays to fog the plate from the back. It is, perhaps, in radiographs of the abdomen and pelvis that want of definition becomes most obvious; its existence can be observed by examining the thorax with the fluorescent screen. A coin, for instance, placed on the surface of the body next to the screen, gives a clear, definite shadow; but if placed on the other side of the body, away from the screen, the shadow becomes lighter, and much less distinct than would be the case when compared with the shadow of a coin as cast by an ordinary lamp at the same distance.

The distance of the tube from the plate, and from the parts to be radiographed, is an important question on account of 'distortion.' When special sharpness is wished for it is no doubt best to have the tube at a comparatively great distance, and to give a longer exposure. In this way distortion may be reduced to a minimum.

Where there are bones in two different planes the image of those nearest the lamp may tend to obscure those near the plate. If a picture of the latter is wanted without the former it is a good plan to have the tube very close. For example, if a picture of the upper part of the spine be desired, the tube may be placed nearer the sternum than if a general view of the heart and lungs were wanted; the bones of the sternum nearest the tube will then be given indistinctly, and their tendency to obscure the image of the vertebræ will be less evident. Clearness of definition also depends upon other conditions. All movement on the part of the apparatus should be guarded against. If the tube is standing on the same table as the coil the vibration of the contact-breaker may be sufficient to shake the tube, and perhaps to cause the tube-holder to shift its position slightly. A similar disturbing effect may be produced on the plate and on the hand or arm of the patient, if they are resting on the table on which the coil is standing.

Movements on the part of the patient often produce hazy pictures, even where there are no defects in the apparatus. These

movements may be voluntary or involuntary. The operator should always take pains to place the patient in a suitable and comfortable position. For taking the hand, wrist, or elbow, the whole arm should rest on the table, and the patient should sit comfortably in the chair, especially when the elbow is concerned. The movement of the shoulder with respiration may cause a slight amount of indistinctness, and clearer pictures of that part will be obtained when the patient is lying on a suitable couch. Pillows or sand-bags may be placed around parts to be radiographed, and the board on which the plate rests should be as rigid as possible.

Involuntary tremors will sometimes cause bad definition. If the patient feel cold, a blanket may be thrown over the body without causing much obstruction to the passage of the rays.

On account of its movements, radiograms of the heart must always be more or less indistinct. Clearer pictures of the thorax may be obtained in special cases if the patient can hold his breath for the interval during which the tube is running, or if a longer time is required the current can be interrupted for a short time to allow time for a fresh inspiration.

Tubes also differ in the sharpness of the images given. The definition would obviously be best when the rays were emitted from a mathematical point, or from a minute area of surface of the anti-kathode. If that be fixed exactly in the focus of the bombardment coming from the kathode, it is sure to become overheated and perforated, and in general the anti-kathode is deliberately placed a short distance away from the focus; this saves the platinum, but impairs the sharpness of the images a little. Osmium and iridium, especially the former, have been found useful for the anti-kathode, and Dr. Davidson has recommended the use of a bead of osmium centred upon a thick piece of aluminium for the anti-kathode. The osmium is able to withstand the concentrated bombardment without disintegration, but for various reasons it has not come into practical use.

To test the definition of tubes, Dr. Mackenzie Davidson employs a small hand-frame with a network of fine wires crossing each other at right-angles, and when this frame is viewed with a screen, if the *x*-rays come from a small point or focus on the anti-kathode, the shadows of the wires as seen on a fluorescent screen will all be sharp, but if the radiant source is larger than a small point they will show soft or blurred outlines.

Photographic Work.—In the development of the exposed plates photographic skill is valuable, hence it is a distinct advantage where possible to secure the development of the exposed plates by experienced hands. The professional photographer, however, will also require some special experience in order to obtain the best results, for the development of a portrait or of a landscape differs widely from that of a Röntgen ray negative. Much depends upon knowing what ought to appear upon a plate. As a knowledge of photography is useful to the operator who wishes to carry out the process with his own hands, the following hints are given: All the usual dry plates of good makers seem capable of giving good results wish *x*-rays, but amongst them may be specially mentioned the Cadett Lightning, the Imperial Flash Light, and the Lumière plates. With the last beautiful results may be obtained, at the cost, however, of a slow development. Many observers have found that slow plates are just as good and as quick as extra rapid ones. For use the plates are taken from their boxes and transferred to opaque paper envelopes in a dark room.

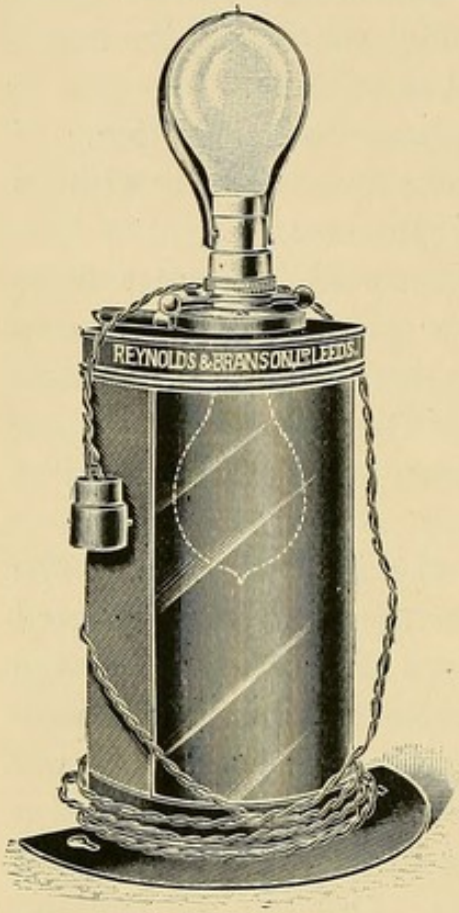


FIG. 59.—ELECTRIC LAMP FOR THE DARK ROOM (REYNOLDS AND BRANSON).

By moving a switch the light is changed from white to red or *vice versa*.

The film should be placed towards the address side of the envelope. It may be recognised in the dark room by its dull, non-reflecting surface, whereas the plain glass side shines and reflects light sharply. Do not bring into the operating-room more plates than the one to be used, as they would in all probability be affected by the Röntgen rays, even if standing a long way from the tube. They can only be kept in the same room if shielded in a box of thick metal. It is an advantage to use one uniform size of plates and the 12 + 10 size is large enough for nearly all work.

Röntgen photographs may also be taken direct on sensitized paper. The Eastman Co. have produced an *x*-ray paper which is

used in exactly the same way as the dry plate. Although these papers are not so good as glass plates, their advantages are of such a kind that improvement is to be hoped for. In using paper or films instead of glass plates, the operator must take care to lay them flat, otherwise the image may be distorted in a remarkable way, and thus give rise to pictures that may entrap the unwary into all kinds of fallacious readings. A good plan is to place the sensitized paper between two sheets of stout pasteboard, or to back it with a sheet of glass or metal.

The methods of development are legion, but only one or two of those that have yielded the best results in *x*-ray work are described here. Most of the makers of dry plates and of sensitized paper print on the cover of the packets a formula which they have found suitable for developing, and in general the plates should be developed by the formula prescribed by the makers and printed on the packets. Developing solutions may be prepared of pyrogallic acid, hydroquinone, rodinal, metol and several other compounds. One drawback to the use of 'pyrogallic' developer is the way in which it stains the hands. To avoid that inconvenience, rodinal or hydroquinone are preferred by many photographers. Metol does not stain the hands, but it is apt to cause a troublesome soreness of the skin.

For many kinds of plate a rodinal solution is efficacious and convenient. The writer has found this developer give excellent results. One part of rodinal is used to 16 parts of water. The image quickly appears, but development must be continued until the negative appears to have gained considerable density. In cases of over-exposure the solution may be diluted.

Good results can be obtained with hydroquinone, which is a slow developer. The image begins to appear in about four or five minutes, and development must be continued for half an hour or more—indeed, until the whole surface has become blackened. To secure detail slow development appears to be desirable.

Metol gives a dense black negative, and combined with hydroquinone is a favourite combination with many Röntgen photo graphers, and has been well spoken of in the following formula:

Metol - - -	80 grains.
Hydroquinone - -	45 ,,
Sodium sulphite (crystals) -	640 ,,
Sodium carbonate (crystals) -	640 ,,
Water - - -	to 20 ounces.

The operator will do well to master the capabilities of one set of plates and of one developing solution.

Dishes—the lighter the better—will be required to suit the various sizes of plates. They may be made in the smaller sizes of ebonite or of xylonite, and in the larger of papier-maché or of earthenware. Having mixed the developer, take the exposed plate out of the envelopes, place it in the developing-dish, hold the dish slightly inclined, and pour the developing solution quickly along the upper edge of the plate, so as to cause it to flow rapidly over the whole surface. Keep the liquid moving during development. The image, if properly exposed, should show within a minute from the time of pouring on the developing solution. In from five to ten minutes the picture should be fully developed. Practice alone will enable one to decide when this important part of the process has been effected, but the film should be darkened through to the glass, so that the back looks blackened when examined from behind. The plate must now be taken out, rinsed in several changes of water, and placed in the fixing solution, which consists of:

Hyposulphite of soda	-	16 ounces.
Water - -	-	80 „

In this it should remain until all traces of unaltered silver salts have disappeared. This can easily be seen by examining the back. It may then be examined by ordinary light, and should be washed in running water for at least an hour, and afterwards placed edgewise to drain and dry.

If time is an object the drying process may be accelerated by soaking the wet negative for a short time in one or two changes of methylated spirit or absolute alcohol. When dry, the negative may be put in the printing-frame, and a print taken.

Intensification of negatives is sometimes necessary to strengthen a faint image, especially in the case of deep tissues taken with a high resistance or 'hard' tube. It is carried out by first washing the developed and fixed plate, and then immersing it in a solution of corrosive sublimate of a strength of 20 grains to the ounce of water, rendered soluble by the addition of an equal quantity of ammonium chloride. The negative is left in this solution until its whole surface turns light gray or white; it is then well washed, and blackened in a solution of strong ammonia—10 drops to the ounce of water. Negatives intensified in this way print slowly. Other intensifying formulæ may be used instead of the above.

Reduction of an over-dense negative may be effected by washing, and then placing in clean hyposulphite solution until it is evenly moistened. The plate is then removed, and to the solution of hyposulphite a few drops of a 10 per cent. solution of potassium ferricyanide in water is added. When the plate is again immersed reduction at once commences, and must be carefully watched. When sufficiently advanced the plate should be rapidly removed and washed to prevent the reduction from going too far, as may easily happen.

CHAPTER IX

LOCALIZATION—STEREOSCOPIC RADIOGRAPHY

The work of Mackenzie Davidson—The localization of foreign bodies—The cross-thread localizer—Stereoscopic Radiography.

EVER since the discovery of *x*-rays the determination of the position of a foreign body embedded in the tissues has received much attention, and numerous ingenious contrivances have been devised for simplifying the measurements involved.

In this country the methods of Mackenzie Davidson are universally employed, and his papers upon localization and stereoscopic radiography remain the standard works upon these subjects, although they were written in 1898. By the kind permission of Mr. Davidson these articles are reproduced below in a slightly abridged form, and as they have not been reprinted since their first appearance in the *British Medical Journal*, it is hoped that they may be in this way rendered more accessible to many readers.*

'It is not enough for the surgeon to have a fine skiagraph of the part of the human frame showing the presence of a foreign body. He wants more than that to enable him to operate with complete confidence. He wishes to know the size of the object, and its position and depth from the skin at any point he may select. Some simple method of localization which can be readily carried out is an urgent need. I believe the method I have devised is of this character, and an apparatus which I have had constructed appears to fulfil these requirements. It was obvious from the first that the taking a skiagraph from two or more points of view was the necessary starting-point to any method of localization, but how should the resulting

* 'Röntgen Rays and Localization: An Apparatus for Exact Measurement and Localization by Means of Röntgen Rays,' by James Mackenzie Davidson, M.B., C.M. Aberd. (*British Medical Journal*, January 1, 1898).

photographs be dealt with so as to give the desired information as to the precise position of the foreign body? This remained a difficulty, except to the comparatively few who were sufficiently familiar with geometrical drawing and mathematics.

'My method is as follows: I take two skiagraphs from two different points of view. In order to carry out the adjustment and movement of the Crookes tube, I use a horizontal bar with a scale upon the front of it, graduated in millimetres, with zero at the middle point of the bar. There is a small holder for the Crookes tube which slides horizontally along the bar, and there are two sliding checks, which can be fixed by means of a small screw at any desired points on the scale, thus enabling the tube to be quickly and accurately moved from a position on one side of zero to a corresponding point on the other side.

'In case it is desired to adjust the tube to any particular height, there is a small bar or carrier which slides vertically up and down, and carries the tube with it and acts as a fine adjustment; a small thumb-screw clamps it. A spirit-level is fixed on the top of the horizontal bar. As far as this part of the apparatus is concerned, it is simply a convenient method of enabling the tube to be displaced in taking the skiagrams, and somewhat similar arrangements have been in use by other workers.

'I shall now describe the method of taking the skiagraphs. In the first place, it is important to note that the kathodal rays give rise to the Röntgen rays at the point where they strike a solid object. The kathodal rays converge to a point, and strike the anti-kathode, and it is at this point that the Röntgen rays originate. Its position is ascertained by observing the spot which begins to get red-hot on the platinum anode. This, then, is the point from which the *x*-rays diverge in straight lines into space; just as with a candle, instead of a Crookes tube, in studying the shadows produced, we would have to know that the light rays come from the flame, and it alone.

'The first process, then, is to measure as accurately as possible the height of the point of origin of the *x*-rays above the photographic plate or film, and generally for all practical purposes the centre of the anode plate may be taken as the radiant point. The sliding holder with the tube is placed with one of its edges at the zero point of the scale on the horizontal bar. The check-clips are adjusted on either side to the desired degree of displacement, and fixed there, so as to allow of equal displacements of the tube to either side. The

amount of displacement of the tube does not seem to affect the accuracy of the results. I have worked with a displacement of 3, 7, and 10 centimetres to each side of zero.

'On the table below the tube there is a large square of vulcanite, with two fine wires stretched across it at right angles, and dividing it into four equal parts. It should be considerably larger than the largest photographic plate or film which is to be used, so that the plate or film covered with black paper in the usual way can be slipped beneath the cross-wires. Or, instead of using a vulcanite plate, the wires can be tied directly across the covered photographic plate. The adjustments now necessary are as follows: Put the tube-holder at zero of the horizontal scale, and then with a small plumb-line drop a perpendicular from the centre of the anti-kathode. The plate is then placed so that the point where the wires upon it cross is vertically under the anti-kathode. Further, note that it must be so placed that one of the wires is parallel to the plane in which the tube is to be displaced—that is, it must be made to lie parallel to the horizontal bar. This can be done by mere inspection by looking along the edge of the horizontal bar, and seeing that the wire is parallel to it. Once these adjustments are made, the plate can be fixed to the table with drawing-pins, and the instrument is ready for use at any time without further adjustments being necessary.

'The distance from the anti-kathode to the plate is carefully measured and recorded. The tube-holder is now displaced to the previously fixed check-clip on one side. The cross-wires are lightly brushed over with some suitable dye—as, for instance, with some of the ink used for rubber stamps. The plate or film, protected from light in the usual way, is then slipped beneath the cross-wires. The patient now places the part to be photographed on the plate, and a small coin or other metallic object is placed on one of the corners of the plate so as to mark a quadrant and serve as a landmark. When all is arranged the current is turned on and one exposure made. The tube is then pushed over to the other side of the zero mark to the portion at which the other check-slip had been previously fixed, and then, without the patient moving, another similar exposure is given on that same plate. When this has been completed, and the patient raises the limb from the plate, he should carry the mark of the cross-wires in ink on his skin, and it is advisable to make a small mark on that quadrant of his skin which corresponds to the quadrant of the plate upon which the coin or

other landmark was placed. This serves to keep the parts and the negative in register.

'(I may here remark parenthetically that in some cases it will be an advantage to drop perpendiculars by means of the plumb-line from the anode of the tube to the patient's skin after the patient is placed ready to be photographed. This can be done from the zero mark and from the two points of displacement of the tube, and at the points where the plummet touches the skin is marked, and the points can then be joined by a straight line. Another can be drawn at right angles from the central point. It is clear that the cross so marked on the upper part of the patient's skin will exactly correspond to the cross left by the inked wire below, and as our method depends upon measurements taken from the cross-lines, it is obviously an advantage to have an upper as well as the lower plane from which to work.)

'On the negative, when developed and fixed in the usual way, we shall find two shadows of the foreign body. If, for example, it be a bullet, there will be two shadows of the bullet in the negative.

'From the above data, and with this negative, one can arrive at a correct knowledge of the position of the bullet by means of mathematical formulæ or by geometrical drawing to scale. But the requisite knowledge is not always at hand; and I think that the method of dealing with the negative which I have devised and will now describe is simple and accurate, and, moreover, is within the reach of everyone who can use a foot-rule and a pair of compasses.

'Fig. 60 shows the apparatus which may be called the "localizer." It resembles a photographer's retouching desk. Upon an iron stand a piece of plate-glass is placed horizontally and level, and beneath this is a mirror which can be adjusted so as to reflect upwards the light from a window or a lamp. There is a horizontal bar which slides up and down upon two vertical brass rods. On this bar there is a millimetre scale with a small notch at each millimetre mark. The o° is at the middle point of this bar. On the glass plate there are two lines cut with a diamond at right angles to each other (just like the cross-wires on the vulcanite plate), and this glass plate, which is movable and can be clamped, is so placed that the point where the lines cross is vertically beneath the o° on the scale above, and the line on the glass running right and left (when facing the scale) is placed parallel to the edge of the scale. In other words, they are in the same vertical plane. The scale is now raised

or lowered so that the zero mark on it stands at precisely the same height vertically above the negative as the anode of the Crookes tube was from the photographic plate or film when the negative was being produced. The whole apparatus stands on screws, so that it can be levelled easily.

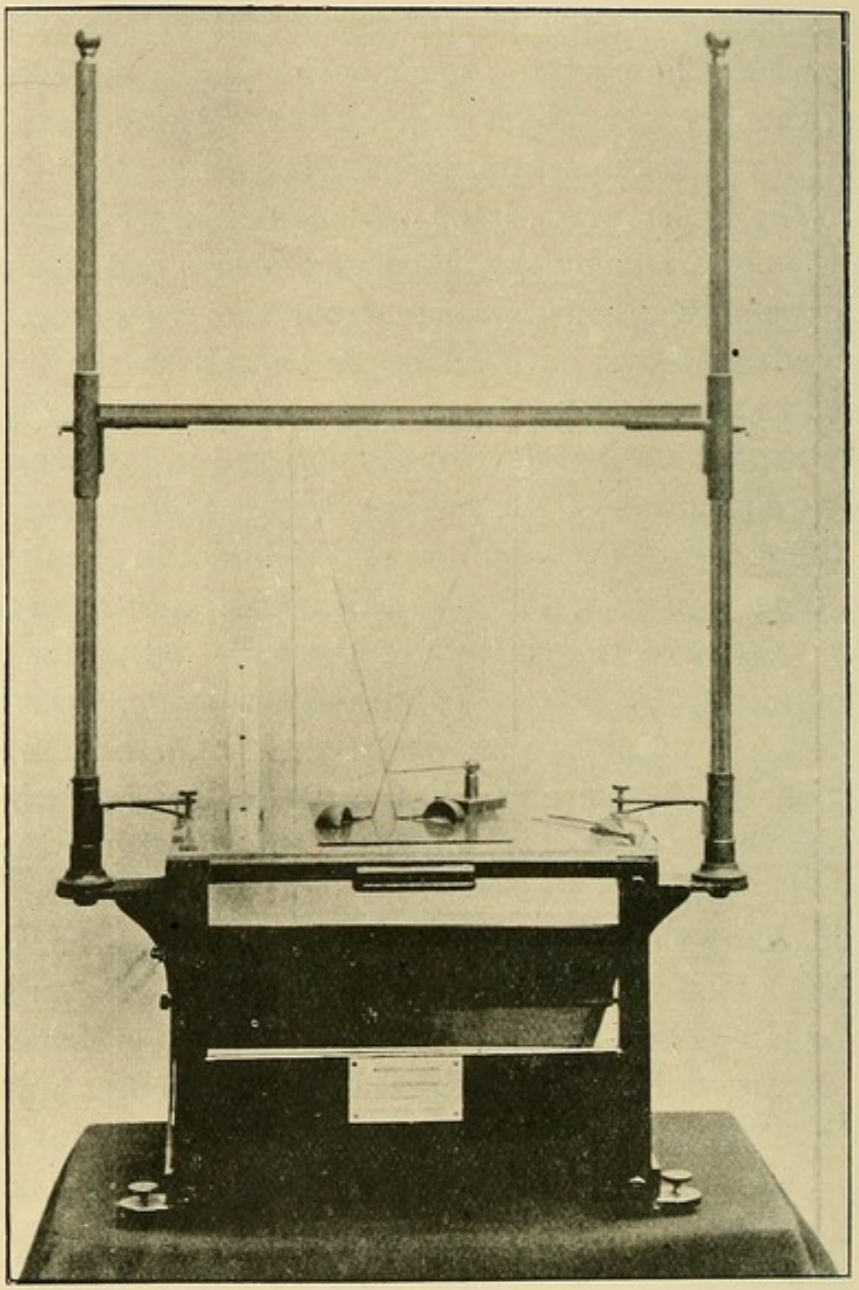


FIG. 60.—MACKENZIE DAVIDSON'S CROSS-THREAD LOCALIZER.

'The negative is placed upon the horizontal stage and adjusted so that the white lines produced by the cross-wires are made to coincide with the crossed lines on the glass plate, care being taken that the marked quadrant is in the same relative position as it occupied when the photograph was being taken. As a routine practice I

always mark the right upper quadrant as I stand facing the scale of the bar.

'It is important to remember that if the negative is placed on the stage with the gelatine surface downwards, the relations of the parts are reversed, and it should be so placed that the marked quadrant, which would be on the right and upper corner if the gelatine surface was upwards, should lie on the left upper corner. However, as the patient's skin has the corresponding quadrant marked upon it, there should be no confusion.

'Matters being thus arranged, it will be seen that I have really placed the negative under exactly the same conditions as it occupied when it was being taken. Under these circumstances all that is now required is to trace the path of the *x*-rays which produced the negative. I do this in a very simple way. The distance on each side of the middle point (zero on the scale) to which the anode was displaced is known. Suppose it was 7 centimetres, I place a fine white silk thread in the notch 7 centimetres to one side of 0°, and I place another silk thread (red) in the notch 7 centimetres to the other side of the 0°. Small weights are attached to one of the ends of each thread to keep them taut, while the other is threaded into the eye of a fine needle which is weighted by being fixed into a small lead weight, in shape resembling a mouse.

'These threads can now be used to show the path of the *x*-rays which produced the negative. Suppose we are dealing with a needle in some part of the body : on looking down on the negative, we find two images of the needle, and it is not difficult to see that, as the Crookes tube was displaced horizontally in a line running right and left, the shadow of the needle to the left was produced by the tube when displaced to the right, and *vice versa*. Thus, if we place one of the threads on the point of the needle in one shadow correctly, it will indicate the path of the *x*-ray that produced one shadow of the needle-point. And if the other thread is placed on the corresponding point of the other needle-shadow, it must follow that the position actually occupied by the point of the needle in question is precisely at the place where the two threads cross.

'If we can measure the perpendicular distance of a point from three planes which are at right angles to each other—in short, if we can get the *x*, *y*, and *z*, we then know all about the position of the point in question.

'This we can do at once with the pointer. First, the vertical distance from the negative to the place where the threads cross each other is measured. This is the distance of the point of the needle from the surface of the skin of the patient which rested on the photographic plate. We can measure this with an ordinary pair of compasses, or with a gauge. If this little instrument has its point placed against a vertical millimetre scale, the distance from any plane vertically to where the point of the pointer rests is read off at once.

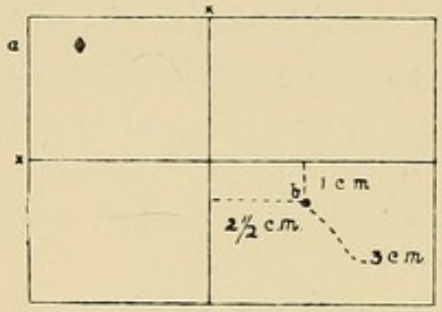


FIG. 61.—DIAGRAM OF LOCALIZATION.

'We next measure the perpendicular distances from the two planes represented by the shadows of the cross-wires to the point where the threads cross. An upright square is placed with its edge coincident with the shadow of one of the wires, and the perpendicular distance is measured with compasses from it to the point where the threads intersect. We now have obtained our x, y, and z of the point of the needle, and we note the result down. The arrows indicate the direction of the displacements of the Crookes tube. If necessary, we may then proceed in a similar manner to ascertain the position of several points of the foreign body—for instance, of its two ends in the case of a needle—and thus we may find the direction and actual length of the needle.

'Several pairs of threads might be used, and in this way the shape of the foreign body might be so far outlined; but it seems to me more convenient to use one pair. The point where they intersect can be fixed by the point of the surface-gauge, and when the threads are moved to another position, the distance between their new point of intersection and their former, where the point of the surface-gauge stands, can be measured at once.

'The final result of the process is that we can draw an outline of the foreign body on the patient's skin, and give the depth below the skin of any of its parts, and this enables us to give the direction and depth at which it can be reached from any other point the surgeon may select. In applying the measurements made from the negative, it is most important to remember that the quadrants are reversed if measurements are made from the negative with gelatine surface upwards. Hence it is preferable to use a film, and to place

it with the gelatine surface downwards. I have described the method somewhat in detail, but it is really very simple, rapid, and reliable, and can be done very quickly after a few practical trials.

'Triangulation by means of threads in the manner I have described is likely to be capable of wider application. I should hope it will prove useful in the measurement of bones, displacements, and especially in pelvic measurements. Provided fairly well-defined double skiagraphs can be obtained (preferably on the same plate), then the measurements by my method cannot fail to be accurate. Mr. Paxton (of Messrs. Curry and Paxton, 195, Great Portland Street, W.) has given me valuable assistance in constructing the apparatus to carry out this method conveniently and quickly.

'I shall conclude by referring to two cases in which successful localization has been made by this method. Mr. Openshaw had a case at the London Hospital in which a needle was supposed to be embedded in a man's foot. An attempt had been made to find it without success. Dr. W. S. Hedley, who has given me most willing assistance throughout, brought the case to me for localization. The first photograph of this case showed that there were two pieces of a needle in the foot. I applied my method to this case, and obtained a negative with the double shadows. The centre of the anode was 56 centimetres above the plate, and the total displacement of the Crookes tube was 14 centimetres—that is, 7 centimetres to each side of the zero point.

'The length of each fragment was correctly estimated, their positions outlined on the skin, and the depth of each extremity given. Mr. Openshaw, from the measurements and indications afforded, extracted the two pieces of the needle readily, making only a very small incision.

'I am informed that the first independent application of this method has been carried out by Professor Ogston, of Aberdeen, and his assistant, Dr. Irvine Fortescue. From my written description an apparatus was constructed which enabled them to locate a needle precisely in a woman's foot, and even to estimate its length correctly to a millimetre. It was successfully removed. It is of interest to note that the patient previously had had a skiagraph taken showing the presence of the needle, and had undergone two unsuccessful operations for its extraction. This case pretty clearly

establishes the advantages of exact localization preceding operative interference.'

For localizing foreign bodies in the orbit certain special procedures are necessary.

The following plan gives reliable results.* 'The patient sits upright in a chair; the back of his head rests against a board. The side of his head (with the eye to be photographed) rests against two knitting-needles, which are placed at right angles to each other across a wooden frame. He is made to fix his eyes on a distant object, and a small piece of lead wire is made to touch and mark the lower eyelid at a point which bears a definite relation to some point of the eyeball, such as a scar, etc. The Crookes tube is arranged to slide horizontally, parallel to the horizontal knitting-needle. Two skiagrams are taken, on the same plate preferably, if possible, or one upon a plate and the other upon a celluloid film, which allows of their being superimposed for localization purposes, the perpendicular distance of the anode being noted from the point where the knitting-needles cross each other, and then the displacement of the tube to each side of this, for each exposure, is also recorded.

'When the negative is placed upon the localizer, we first determine the position of the point of the wire that rested on the lid, and leave a needle with a fine point to indicate this position. We then ascertain the position of the foreign body, and we can thus find out the distance and direction of the foreign body from the mark on the lower eyelid when the eye is placed in the same position as it occupied when the skiagrams were being taken. It is thus possible to ascertain the position of a foreign body in the eyeball or orbit with considerable accuracy, and also to give its size to within $\frac{1}{25}$ to $\frac{1}{15}$ inch.

'In one of Mr. Treacher Collins' later cases this was proved; and in Mr. Lawford's case, where the eyeball had to be removed, a particle so small as $1\frac{1}{2}$ by $2\frac{1}{2}$ millimetres was located, and the sizes in the two diameters I had estimated at 1 by 2 millimetres, an error of $\frac{1}{50}$ inch.'

Stereoscopic Radiography. — The important advantages to be obtained from taking two photographs and viewing them

* 'On the Localization of Foreign Bodies in the Eye and Orbit by the Röntgen Rays, with Illustrative Cases,' by Mackenzie Davidson and E. Treacher Collins (*British Medical Journal*, August 20, 1898).

stereoscopically has been insisted on by Mr. Mackenzie Davidson.* His paper is so important that it is reproduced here with certain modifications.

'It is only necessary to look at two good stereoscopic radiographs in a Wheatstone's stereoscope to realize at once how thoroughly practical and important this method is in surgical work. A single skiagraph is often confusing, if not misleading, but with two properly taken and viewed in a stereoscope the picture stands out in true relief, and shows clearly the relation of the parts.

'Two radiographs must be taken from two different points of view. After one has been taken, the Crookes tube must be displaced and then another taken. I use the horizontal bar of my localizing apparatus as a support for the tube. Any desired displacement may be given to the tube; but it seems best to displace it about 6 centimetres, which may roughly be taken as the distance between our eyes. The two skiagraphs thus taken from two different points of view, and the necessary marks made on the patient's skin to guide the surgeon, give data sufficient to localize the position of any foreign body accurately by means of a localizer, while the same skiagraphs, when viewed in the stereoscope, give a picture enabling the surgeon to have a correct relative view of the parts in relief. This method, if correctly carried out, is so accurate and complete that the surgeon can have little cause for complaint.

'In order to insure that the two plates shall be in correct register, a changing-box is used. This consists of a frame over which is tightly stretched some calfskin. This is stout enough to support a considerable weight, and at the same time is thin and transparent to *x*-rays. The photographic plate, wrapped in black paper in the usual way, is placed beneath the skin, and supported against it by some suitable arrangement. A horizontal bar carries the tube-holder, and permits it to be displaced to either side, and a pair of clips may be used to fix the limits to which it must be displaced for the two photographs. A wire is stretched along one side of the changing-box, and the bar is arranged parallel to this wire. This leaves a white line at the edge of each negative, and this enables the photographs to be mounted correctly in register. When in position the plate is brought firmly up against the calfskin. The part of the patient to be skiagraphed is placed upon the top of the box. It will be easily seen how two photographs can be taken on

* *British Medical Journal*, December 3, 1898.

different plates without disturbing the position of the patient; we are thus sure of obtaining correct stereoscopic pictures. This method can, of course, be carried out by having a table made with calfskin covering a space cut out of the top; or, again, an operating-table can have a window, so to speak, covered by the calfskin, upon which the patient can lie. This has the further advantage that it will allow a Crookes tube to be placed below this part of the table, so that the patient could be examined by a fluorescent screen while lying on the couch.

'**Wheatstone's Stereoscope.**—Two plane mirrors, about 4 inches square, are so fixed on a vertical support that their backs form an angle of 90° with each other. When the observer puts his face

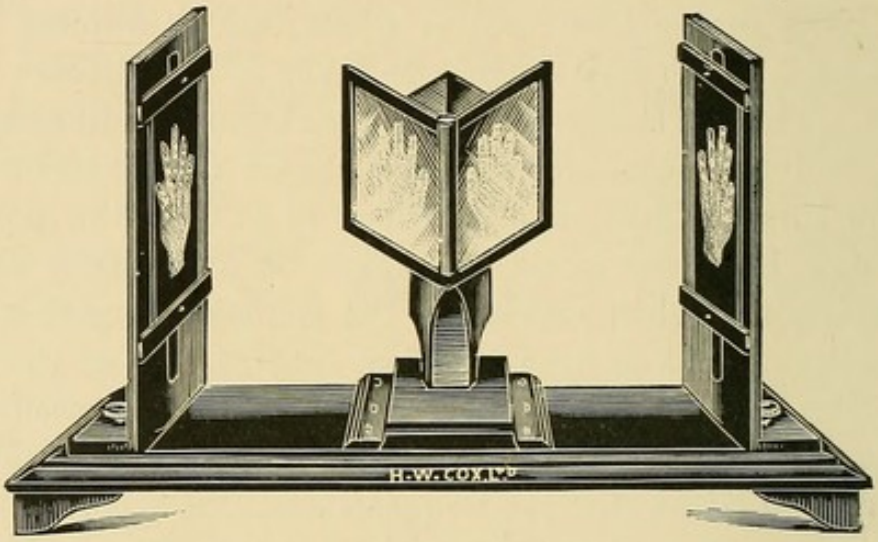


FIG. 62.—THE WHEATSTONE STEREOSCOPE.

close to the edge where the mirrors meet, so that this edge lies vertically between his eyes, it follows that his right eye can only see what is reflected in the left mirror. Now, if the two skiagraphs, taken as already described, are placed so that the right eye image is opposite the right mirror, and the left image opposite the left mirror, each eye will recognise its own picture, and they will combine, as usual, and give rise to a single image in perfect relief.

'The Wheatstone stereoscope is peculiarly adapted for *x*-ray photographs—first, because, as everyone knows, a print from an *x*-ray negative is reversed; for example, if a skiagraph of a right hand be taken, when printed it appears to be a left hand. Now, if such a print be viewed in a Wheatstone stereoscope, it is reflected in one of the mirrors, and is thus reversed to its original position by the reflection. Therefore, if opposite the right mirror is placed the

print from the negative produced when the Crookes tube was displaced to the right side, and opposite the left mirror the print from the negative taken when the tube was displaced to the left, the observer will then see the parts in correct stereoscopic relief, as if he had been looking at them with his eyes placed so that the right eye was at the point occupied by the anode when displaced to the right, and the left eye at the point occupied by the anode when the tube was displaced to the left. If the skiagraphs be viewed under the same angle as they were taken, the stereoscopic picture would show the parts of the true or actual size, and the exaggerated distortion of the single *x*-ray photograph is overcome. The importance of such a result to a surgeon is great.

'If the right picture be placed opposite to the left mirror, and the left picture opposite the right mirror, a stereoscopic picture will be seen as before, only reversed. For example, in one case a hand will appear as seen from the dorsal aspect; if the prints are transposed, it will appear as a hand seen from the palmar aspect. The same transposition can be effected by turning each print upside down.

'The negatives, when wet, can be seen in a stereoscope if they are held in a proper position by upright frames, and each illuminated by a strong light diffused through ground glass or white paper, but the effect is not so good as viewing prints.

'There is no limit to the size of the pictures which can be seen in a Wheatstone stereoscope. The largest size the writer has as yet taken stereoscopically is 12 by 15 inches.

'There are several devices for supporting the skiagraphs, and also for simultaneously making them approach or recede from the mirrors. The simplest of all arrangements is to have two mirrors mounted on an upright block of wood, which can be placed upon a table, while the skiagraphs can be supported by any simple means in the proper position.

'The block supporting the mirrors is attached to a small base with bevelled edges, which slides in a broad groove, and enables the observer to slide the mirrors towards or away from his eyes. In this way he can adjust the mirrors to the position which enables him to combine the pictures most comfortably. Each revolving-box is fixed by its vertical support to its sliding-board. This allows the distance of the skiagraph from the mirrors to be altered at will.

'The writer has devised a form of revolving Wheatstone stereoscope. A four-sided box, which can be revolved on a vertical rod,

is placed opposite each mirror. Upon each of its four sides one of a pair of stereoscopic skiagraphs is placed. The corresponding pictures are similarly placed on the other box. In this way the boxes can be rotated, and two corresponding skiagraphs brought simultaneously in correct position opposite the mirrors. This prevents the necessity of adjusting each pair separately, and saves time in demonstrations.

'By practice it is not difficult to acquire the power of combining stereoscopic pictures without an instrument of any kind. There are two ways of doing this:

'1. By looking beyond the photograph, so that each eye sees the picture opposite it.

'2. The most easily acquired and most important for *x*-ray work, as it enables skiagraphs of any size to be seen at once, consists in crossing the visual axes. This may be accomplished as follows: The photographs or radiographs are placed correctly in front of the observer; he then holds up his finger in the middle line between his eyes and the skiagraphs, and while looking at the top of his finger he will observe double images of each radiograph. By a little perseverance he will learn to make the two images in the centre combine, and he then will have a beautifully clear stereoscopic image apparently in the air. Behind to the right and left will be two images, but these he soon learns to ignore, or he can cut them off by bringing his hands cautiously from the outer side of each eye towards the middle line, stopping the moment the two side images are cut off. It is, of course, convenient in this way to see negatives in stereoscopic relief immediately after development.'

Other forms of reflecting stereoscope may be used. A very convenient kind is one known in France as the stereoscope of Cazes. In this the pictures to be viewed lie flat on the table below the mirrors, which are supported on a brass pillar. This disposition of the apparatus has certain advantages.

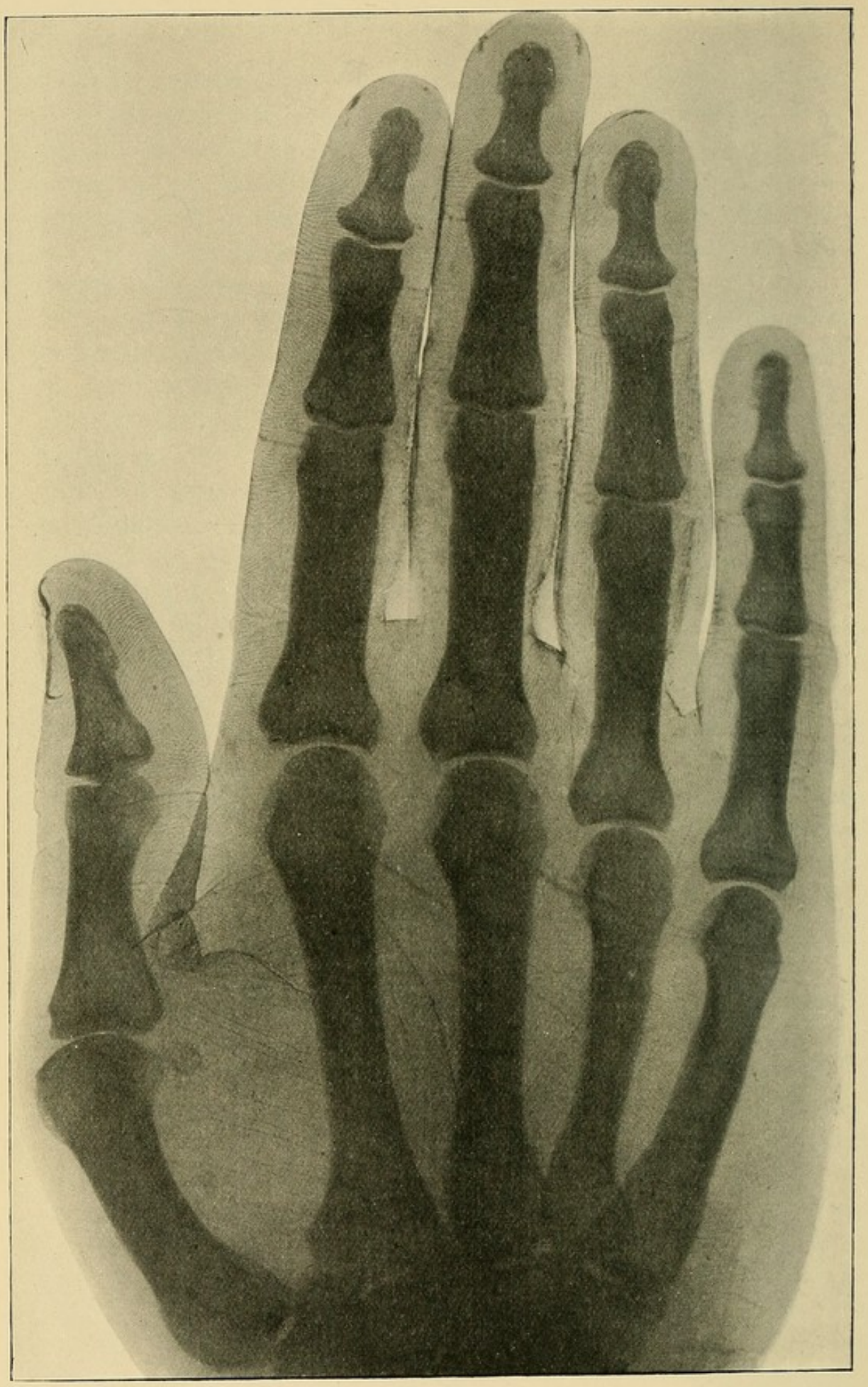


FIG. 63.—HAND SHOWING SKIN MARKINGS.
Dr. Walsh's Method. (Best seen with a magnifying glass.)

PART II

MEDICAL AND SURGICAL APPLICATIONS

DAVID WALSH, M.D.

THE advantages of Röntgen ray work to the medical man are not confined to purely clinical purposes, but are here and there extended to other branches of professional study, such as forensic medicine, anatomy, and physiology.

In order to deal with the subject systematically, it may be split up into various sections. The following classification will be found to cover most of the ground broken by this modern means of accurate investigation.

A. Surgery.
- I. Foreign Bodies.
- II. Bones.
  - (*a*) General Remarks.
  - (*b*) Fractures and Dislocations.
  - (*c*) Separation of Epiphyses.
  - (*d*) Congenital and other Bony Deformities.
  - (*e*) Diseases of Bone.
  - (*f*) Other Surgical Points.
  - (*g*) Action of Rays upon Micro-organisms.
- III. Mapping of Skin Surfaces.

B. Dental Surgery.

C. Nasal and Throat Surgery.

D. Medicine.
- IV. Regional.
  - (*a*) Thorax and Abdomen.
  - (*b*) Heart and Great Vessels: Aneurism, Cardiac Enlargement, etc.
  - (*c*) Lungs and Lung Diseases: Pleurisy, Phthisis, etc.
  - (*d*) Abdomen.

V. Other Medical Points.
VI. Action on Skin and Deeper Structures.
VII. Therapeutics.

E. Obstetrics and Gynæcology.
F. Legal Medicine.
G. Anatomy.
H. Physiology.
I. Veterinary Uses.

A. SURGERY

When the first Röntgen photographs were published, scientific surgeons all over the world became keenly alive to the possibilities of the situation. So far, they have gained the lion's share of practical help from the new science, but the process has also proved of great and increasing value to the physician. As methods improve, they will both assuredly derive a still greater amount of precise and valuable information from the same source. Their future progress, however, will most likely depend upon the definition of the more translucent structures and bodies, such as soft tumours, gall-stones, uric acid calculi, abscess cavities, internal organs, and so on. So long ago as February, 1896, Adolph and Leng recorded the fact that they had obtained a Röntgen ray picture of ordinary connective tissue.

I. FOREIGN BODIES

In nothing have the Röntgen methods proved of more immediate practical use to the surgeon than in the finding of foreign bodies. The nature of the embedded substance is of importance, for, in order to yield a readable record, it should offer a resistance to the rays considerably greater than that of the tissues in which it lies. Thus, a bullet buried in translucent muscle would cast a deep and clear-cut shadow on the sensitive plate or screen, whereas it would be obscure if lodged in more opaque structures. Fragments of glass can be readily photographed, because they resist the rays, but such penetrable materials as leather, clothing, paper wads, and wood, cannot, as a rule, be demonstrated by radiography.

All surgeons know that at times it is impossible by any ordinary method of examination to detect the presence of a foreign body in the deeper tissues. A familiar instance of this uncertainty is met with in the palm, where a fragment of needle may elude not only

careful and skilful manipulation, but an extensive cutting operation as well. The help that can be given by the Röntgen rays under kindred circumstances may be judged from the following cases that have been brought under the writer's notice :

A lady, who some time previously ran a needle into her hand, had her palm explored by a surgeon, with negative results. A little later a radiogram, taken through splint and dressings, revealed a piece of broken needle lying in the first interosseous space, close to the distal end of the thumb metacarpal. From the information thus obtained the foreign body was readily removed by a second operation. In other words, the process furnished the surgeon with a method of diagnosis which denoted not only the presence, but also the shape, nature, and approximate position of the body to be removed.

In another case a child suffered for several weeks from a swollen foot, for which no cause could be ascertained. A radiogram, however, showed fixed in the astragalus a broken needle, the removal of which was followed by speedy recovery.

In many cases the surgeon cannot locate the foreign body with any precision by means of a single radiogram. For instance, it may be impossible to say whether a fragment of needle is on the dorsal or the palmar aspect of a metacarpal bone. A second photograph taken at right angles to the first, or a stereoscopic photograph, will furnish the desired information. The same end may often be attained by a screen examination in the hands of a skilled observer.

These facts suggest a useful application of the Röntgen rays—namely, to locate a hypodermic needle broken off beneath the skin. As everyone knows, such an accident may be caused by an abrupt movement on the part of the patient. Further, the fragment is apt to wander about freely, so that few surgeons would feel justified in undertaking a cutting operation unless the foreign body could be fairly well localized. The danger to the host of a wandering object of the kind in the tissues is obvious, and the surgeon should always insist upon having the radiogram taken at the time of operation. A needle often changes its position from day to day so rapidly that yesterday's record of its position may mislead the operator. Suppose, on the other hand, the fragment to be small and buried, say beneath periosteum or in the sheath of a tendon, it would almost certainly elude the exploring finger of the surgeon,

unless he be guided by the exact information now available in all cases by means of a localizing Röntgen photograph.

The opacity of glass* to the rays, probably due to the contained lead and other metals, makes it easy to detect fragments buried in the soft tissues. It is, of course, well known that such objects may remain embedded for many years, and often give no sign of their presence beyond some slight enlargement and pain or discomfort on deep pressure. By the Röntgen method, however, a foreign body of that sort may be so precisely localized that the surgeon can cut down upon and remove it without a moment's hesitation. After any injury by glass, indeed, it would be well as a routine practice to examine with the rays, in order to ascertain whether any splinter of glass has been left in the wound. In the next case negative evidence was obtained as to the presence of glass, but positive testimony as to the existence of joint mischief.

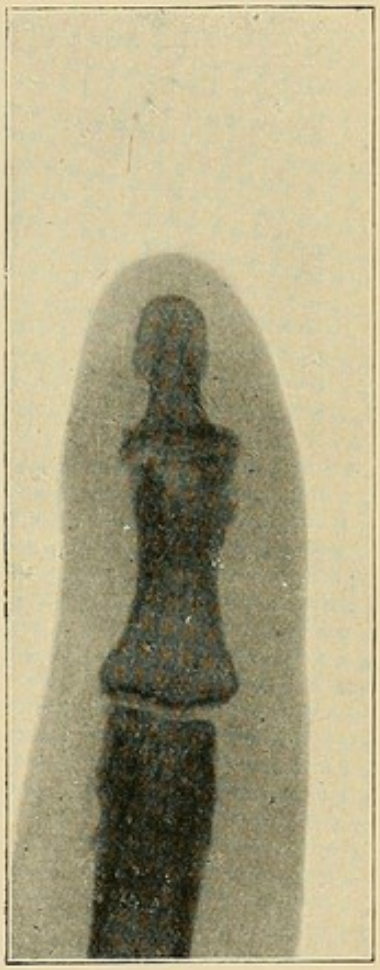


FIG. 64.—FINGER SHOWING ABSORPTION OF BONE AND FIBROUS ANCHYLOSIS.

A. B——, a milliner, admitted to the Metropolitan Hospital with the following history. Two months previously her little boy, whom she was nursing, by a sudden kick broke a wineglass in her hand. The left forefinger was cut, and severe pain followed, reaching up the arm to the shoulder. A piece of glass was supposed to be in the wound, which had been explored before the patient came to the hospital. On admission the wound was found healed, and the end-joint of the finger stiff. The accompanying radiogram (Fig. 64) proved the absence of glass, but disclosed various changes in the joint. Absorption of the distal end of the second phalanx had taken place, and fibrous anchylosis was diagnosed from (*a*) the appearance on the photograph of a faint line between the phalanges, and (*b*) the stiffness of the joint.

Lead being exceedingly opaque to the rays, the Röntgen method

* Potash glass is more translucent to the rays than lead glass.

does yeoman's service in gunshot wounds. The erratic course taken by bullets after entering the body often renders their discovery, under the conditions of ordinary surgery, a matter of impossibility. By means of a Röntgen ray examination, however, the surgeon may almost always acquaint himself as to the exact whereabouts of the missile, without undressing the patient and without taking off splints and bandages, so that the shock entailed by prolonged manipulation may be now avoided. The Röntgen method may also be of service in this class of wounds by proving the absence of a bullet. In doubtful cases the value of such negative evidence, both to the surgeon and to the patient, is so obvious that it need not be enlarged upon.

The difficulty of gaining exact evidence as to the presence of a rifle-bullet was well illustrated in the classical case of Garibaldi. Day after day his medical attendants, surgeons of European fame, endeavoured in vain to find out whether a ball was or was not embedded in the ankle of their illustrious patient. At length Nélaton settled the point by means of the ingenious probe that bears his name, an instrument tipped with porcelain, on which the leaden bullet traced an unmistakable billet. Röntgen, however, has far surpassed the French surgeon's plans as regards ease, certainty, and simplicity, and had his method been available in the case of Garibaldi, a few minutes would have sufficed to clear up the diagnosis. A similar localization might possibly have saved the life of the late United States President, Garfield. It is interesting to add that in 1896 the presence of a Japanese bullet in the head of the distinguished Chinaman, Li Hung Chang, was demonstrated by the Röntgen rays during his visit to Europe.

A bullet was discovered by means of a radiogram lodged near the dorsal spine of Maître Labori, the brilliant counsel who defended Captain Dreyfus. He had been shot in the back by an assassin, but his political opponents did not hesitate to assert that the alleged attack was merely a trick to gain sympathy. The demonstration of the bullet by a Röntgen photograph afforded conclusive proof to the contrary.

In the case of President McKinley, the *x*-rays were not used to locate the bullet. It seems likely that the surgeons in attendance regarded the evident wound of the stomach as the indication for operation without a moment's delay. As shown later the fatal termination would not have been averted by the location and removal of the bullet.

Military Surgery.

In military surgery the Röntgen processes have proved of great value. On a campaign, where baggage is cut down to the last ounce, some difficulty is presented by the cumbersome nature of the necessary apparatus. However, the electrical engineers have already to a great extent met the wants of the case. As it is, an ordinary field ambulance waggon may be calculated to carry a ton burden, a weight that would more than accommodate an *x*-ray installation with dark-room and photographic requisites. In the British Army the Engineers possess a photographic waggon, which might be adapted to such work. However, the Röntgen apparatus would not as a rule be located in the front, but at a field, or, better still, at a base hospital, where bulkiness would not be so positive a hindrance.

Hitherto the chief appliances for detecting deeply-placed bullets have been based on (*a*) simple, and (*b*) electrical contact. Of the former, the two best are Lecomte's *stylet-pince*, made to bite away a morsel of the metal, and Nélaton's probe, which, as already stated, is marked by the lead. Electric probes, on the other hand, are constructed to show, by means of bell, galvanometer, or microphone when the circuit is completed by a bullet touching the end of the probe. The two first-mentioned instruments, however, are useless when dealing with modern hard-mantled projectiles: the stylet-pince fails to bite, and Nélaton's probe to indicate the small-bore ball with its steel or cupro-nickel envelope. Clearly, no such difficulty awaits the method of Röntgen diagnosis, which will at once demonstrate, not only the position, but also the exact size and shape of a missile in any part of the body.

The first opportunity of the trial of the new discovery in actual warfare was afforded by the Græco-Turkish War. The *Daily Chronicle* sent off a complete outfit to the seat of the war in connection with its national fund for the wounded.

Surgeon-Major Beevor carried out the Röntgen methods successfully on the Indian frontier during the Chitral campaign in 1898. His work was often carried on in a temperature that registered 22° of frost and over. The only damage to his coil was on a train journey in Central India, when the insulating wax melted owing to the intense heat. He was able to repair the damage, however, and after that wrapped the coil in damp blankets. He found the method valuable in many surgical conditions other than the presence of a

foreign body, as, for instance, in abscess, necrosis, undetected partial fractures, and injury to internal organs. In one case the spleen was penetrated. In another a round bullet, driven by poor native powder, passed at low velocity through the liver: but the missile did not injure the plexus of nerves and vessels in traversing the body to a position between the ninth and tenth ribs, where it was located by the rays. This diagnosis could not have been attained by probing or other ordinary surgical procedures short of laparotomy.

In the brilliant campaign brought to a close at the latter end of 1898 by the Sirdar, now Lord Kitchener, the value of the Röntgen methods was demonstrated under different climatic circumstances. In the face of great difficulties Major Beevor, R.A.M.C., applied them in the cold and mountainous districts of Northern India, whereas Major Battersby, R.A.M.C., in the Nile expedition encountered the not less trying conditions of sand-storms and tropical heat. The latter distinguished officer, who was in charge of the Röntgen ray apparatus in the Soudan, related his experiences in a graphic manner in a paper read before the Röntgen Society of London, January 10, 1899.* The chief points raised may be thus summarized:

First of all, it may be noted that the work was carried out in a climate where the temperature varied from 100° to 120° F. The destructive effect of that degree of heat upon insulating materials, upon fluids of batteries, and upon the processes of photography, may be readily imagined.

Between Wady Halfa and Abadieh the Soudan outfit had to travel for two days and a night in an open truck, exposed during the daytime to the fierce heat of a blazing sun. By keeping the casing of felt wet, however, the journey's end was reached without mishap, and a thermometric observation showed that the temperature in the interior of the coil did not exceed 85° F.

It may also be noted that Battersby is clearly of opinion that the more perfect appliances for war purposes will dispense with batteries and coils. 'An ideal apparatus,' he writes, 'would consist of a statical or friction machine—some modification, for instance, of Mr. Wimshurst's, by which the focus tube could be excited directly. For such a design many physical difficulties confront us, but they are not insurmountable.'

Portability must always be a first essential in field work. So

* See *Archives of the Röntgen Ray*, February, 1899.

far as the coils were concerned, Battersby had one constructed in two parts, so that they could be slung one on each side of a mule or a camel. Each portion was packed in a teak box—the coil in one, and in the other condenser, commutator, break, and stand. These boxes were cased in thick felt, and also those containing the storage batteries, so that they could be constantly wetted, and their interior temperature thereby reduced by evaporation.

The generation of electricity was managed in a highly ingenious way, which may be described in Battersby's own words: 'The pulley of a small dynamo is connected by means of a leather strap with the back-wheel of a specially constructed tandem bicycle. The required velocity for the dynamo is thus obtained, and our procedure is as follows: Having carefully adjusted the circuit with the storage battery, and also with the voltmeter and ammeter, my warrant officer took his position on the seat of the bicycle and commenced pedalling. When 15 volts and 4 ampères were registered, the switch close to the handle of the bicycle was opened, and charging of the battery commenced. As the resistance became greater, a sensation of riding uphill was experienced, and the services of an additional orderly were requistioned for the front seat. The switch was turned off before pedalling ceased, in order to avoid any discharge from the battery.

'Our cells were the ordinary E.P.S. cells, 40 ampère hour type, with a voltage of 2 volts per cell, and discharge of 4 to 6 ampères. The cells while being charged required the dynamo to give a current of 5 volts and 6 ampères; this multiplied together gives an electro-motive force of 90 watts, and as 760 watts equal 1 electric horse-power, $\frac{1}{8}$ horse-power was necessary to drive the dynamo for charging. It was also necessary to have an extra $\frac{1}{8}$ horse-power to overcome the resistance of the working parts and the opposing force contained in the full batteries, hence the necessity of tandem seat for extra man.'

Primary batteries are for various reasons unsuitable for military purposes. The small dynamo above alluded to was readily transported by rail and river, but was unsuited for carriage by mule, camel, or by bearers. One of the 10-inch coils and its accessories packed in an oak box was found too heavy for mule or camel transport, but when slung by ropes on a long pole could be carried, like an Indian dhoolie, on the shoulders of four men. Beevor advocates bearers above all other means of transport.

The insulated wire for the various parts of the apparatus should be specially made to withstand hot climates.

The tubes were ordinary bianodic focus tubes. Their platinum terminals were protected at the ends of the tubes by a thick ferrule of indiarubber. Each tube was wrapped in cotton-wool and packed in a small wooden box, which appears to have secured safe transit.

The fluorescent screen was most useful at night, but unsatisfactory during the day, owing to the intense glare of the sunlight. Its surface was protected by celluloid, a most necessary precaution in a hot and dusty climate. This appliance is looked upon by Major Battersby as of surpassing importance in military surgery, where rapid diagnosis is everything.

Battersby used glass plates to the exclusion of celluloid films and sensitized paper. Those plates that had the thinnest film were most suitable for the intense heat, and an alum-bath was essential in all cases. The water available for developing was comparatively hot, and no ice was to be got, so that the more delicate shades of development had to be sacrificed. There was a marked tendency for development to proceed at a very rapid pace, often making the picture flash up at once. As a rule, this part of the work was done at three in the morning, that being the coolest part of the day.

Spent bullet wounds are of common occurrence in fighting with natives whose powder is not of very good quality. In former days it was difficult to ascertain whether a bullet had lodged in such a wound or not, and consequently a good deal of probing was resorted to. All that is now changed, as shown by several of Battersby's cases. In one of the latter a private had gunshot wounds on the outer and the inner side of the left arm, and a third near the lower angle of the shoulder-blade. Three pieces of lead were shown by the rays at the outer side of the humerus. No bullet was seen in the chest, the wound in which was consequently not probed. Another soldier was shot near the tip of the right shoulder behind the acromion. The bullet was localized at right angles to the axillary border of the scapula, 2 inches below the glenoid cavity, and readily extracted.

In several instances where the foreign body could not be made out by the screen, owing to the flickering of the tube or the glare of diffused sunlight, a diagnosis was nevertheless afforded by a photographic plate, even when the latter was much damaged and imperfect. In this way a bullet was found flattened out like a

shilling at the lower end of a leg, and an injured hand was shown to have the metacarpal of the ring-finger fractured.

The experiences of the Röntgen method in the Græco-Turkish War, in the British expeditions to Chitral, the Soudan and South Africa, as well as in the Spanish-American War, prove conclusively that it may be applied under all conditions likely to be met with in campaigns. Localization seems to be satisfactory, but much remains to be done in the generation of electricity, in the introduction of portable machines of the Wimshurst type, in the improvement of photographic films and sensitized papers, and in the perfecting of screen appliances. In short, the army surgeon, taught by the experiences of the field, must look to mechanical and scientific experts for advances in the direction of portability, simplicity, strength, accuracy, and durability.

Discussing the best kind of Röntgen ray apparatus for military use, and the place in which the apparatus should be used, Borden, an American army surgeon, arrives at the following general conclusions:

'First, the place for the apparatus is at general hospitals, permanent hospitals on the line of communication, and on hospital ships.

'Second, that, in equipping base and general hospitals for war service, coil apparatus, actuated by primary batteries, should be supplied.

'Third, that in permanently-established hospitals, where there is no dynamo current available, the static machine will probably give most satisfaction, especially if motor power can be had.

'Fourth, that in permanent base hospitals, or on hospital ships supplied with direct currents of 110 to 120 volts, the "break-wheel" apparatus will give the highest obtainable efficiency.'

The above was written in December, 1899, and deals with experiences of the year 1898. It is likely that equally good results might be obtained with mercurial breaks as with Edison's 'break-wheel.' The following description of the latter apparatus is taken from Borden's book.*

'The distinctive feature of the "break-wheel" apparatus is that there is no vibrator on the induction coil, its place being taken by an instantaneous air break-wheel device. This device consists of two toothed wheels mounted on the same shaft, the projections, or teeth, making contact with two flat brushes which bear on the outer peripheries, and by which the current is brought in and led out again. These wheels are rotated at very high speed by a small direct-current motor, which also runs a pressure-blower. The air blast from this blower enters a bifurcated tube, and is connected with two flat nozzles immediately over the contact brushes. When the device is set in operation by starting the motor and connecting the primary of the coil in series with the binding-post, the spark, formed at the contact brushes when the coil is energized, is instantaneously blown out by the air blast at the moment of formation. This greatly increases the rapidity of change in the magnetic circuit, and consequently vastly augments the

* 'Röntgen Ray in Spanish-American War,' p. 28.

electro-motor force in the secondary coil. In consequence, Röntgen radiation of higher penetration and efficiency is produced in the tube. The apparatus can be worked only by 110 to 120 volt direct current.'

Mr. Makins* has written an excellent book giving an account of his surgical experience in the South African War. It contains a number of excellent radiograms and descriptions of gunshot wounds. By the author's courtesy is inserted the accompanying figure, which should prove useful for the radiographer called upon to interpret gunshot fractures :

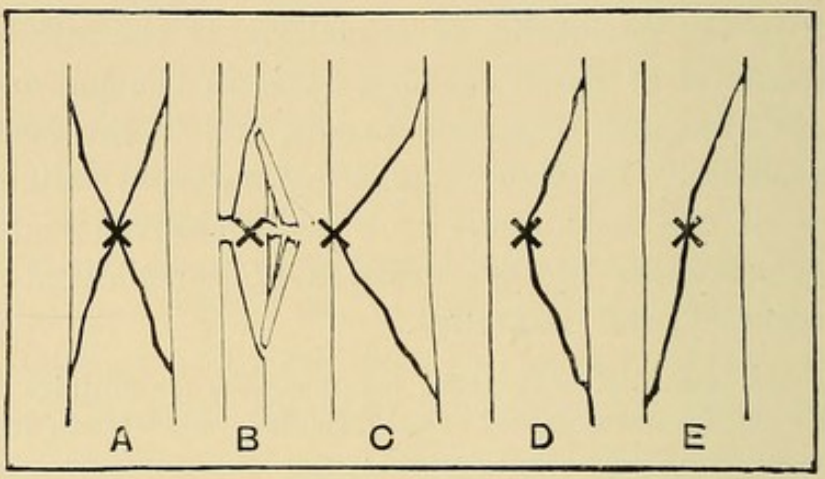


FIG. 65.—FIVE TYPES OF FRACTURE.

A, Primary lines of stellate fracture ; wedges driven out laterally and pointed extremities left to main fragments. B, Development of same lines by a bullet travelling at a low degree of velocity ; suppression of two left-hand limbs and substitution of a transverse line of fracture ; a spurious form of perforation. C, Typical complete wedge. D, Incomplete wedge ; impact of bullet, lateral or oblique, and two left-hand lines seen in A are suppressed. E, Oblique single line, one right and one left hand line seen in A suppressed. The influence of leverage from weight of the body probably acts here.

Mr. Clinton Dent,† special war correspondent in South Africa for the *British Medical Journal*, has given some interesting notes on bone injuries due to Mauser bullets. He concludes that the difference between such injuries inflicted at short and at long ranges is less than would be expected. A far more important factor is the part of the bone struck. Bullets striking the enlarged and highly cancellous ends of the long bones appear to drill without fracture only in certain positions, such as patella and lower end of femur ; fracture is common with drilling of the tibia, upper and lower ends, and of the humerus and radius.

The extent of damage to the compact tissue of the shafts of long bones is naturally greater. A great deal depends on the angle at which the bullet strikes the bones, partly, no doubt, because of its effect in distorting the missile. The writer makes the pertinent remark that a line drawn between the apertures of entry and of exit does not afford a trustworthy clue of the course of the bullet.

On the whole, he does not advise immediate radiography at the front in the case of fractured femurs. The difficulties, he points out, in getting a satisfactory radio-

* ' Experiences of the South African Campaign,' G. H. Makins, F.R.C.S., late Consulting Surgeon South African Field Force.

† *British Medical Journal*, April 21, 1900, p. 969.

gram of that part in a muscular young man are considerable. The patients have to be transported a long distance, and any good that might be gained by a radiogram would be more than counterbalanced by the harm that would result from disturbing the patient. The use of the rays, therefore, was usually deferred in injuries of the long bones of the lower extremity until some union had taken place.

Gunshot Wounds in Civil Practice.

Apart from military surgery, however, there are numerous gunshot wounds in civil practice. It is surprising the number of injuries of this kind, accidental and otherwise, that come under treatment in the course of a single year at one of the great general hospitals of the Metropolis. Many practitioners will readily recall the long and fruitless search for the missile that usually took place in their student days. Now all that is changed, and if a bullet be present, it may, as a rule, be located within a few minutes by the Röntgen ray apparatus to be found in every well-appointed hospital.

One great advantage of the new method is the avoidance of the risk of introducing harmful micro-organisms into the wound by means of the probe. In fact, the method may be regarded as an addition of prime importance to aseptic surgery, and it has done much to lessen the suffering and mortality hitherto incident to gunshot injuries. A further gain is that, with an exact knowledge of locality, the surgeon can minimize the extent of his operative measures. The latter point is well illustrated in the following case, reported in 1897 by Dr. E. H. Lee to the Chicago Academy of Medicine:

'The removal of foreign bodies by means of skiagraphs,' he remarked, 'has opened up a great field of observation in that line. I have in this connection an interesting case, which was that of a policeman who, in pursuing a burglar, shot himself in the heel. The skiagraphs show the bullet embedded in the upper portion of the os calcis. I located the bullet before removing it by Girdner's bullet-probe. By the skiagraph it is seen that the bullet is not located in the joint. This is a point which was of the greatest importance, for the joint was not opened during the operation. It was supposed that we could not remove the bullet without opening the joint, and it could hardly have been avoided had we not had such accurate knowledge of the location.'*

It will be seen, therefore, that the Röntgen methods furnish, as it were, an absolute chart upon which the surgeon may found,

* *The Journal*, Chicago, January 16, 1897, p. 124.

not only his diagnosis and plan of operation, but also the hardly less important point of prognosis.

Bullet lodged in the Axilla.

In one case a radiogram, taken by Dr. E. G. J. G. Calverley, of the Portland Field Hospital, showed a bullet lying between the axillary artery and vein. The entrance wound was a little

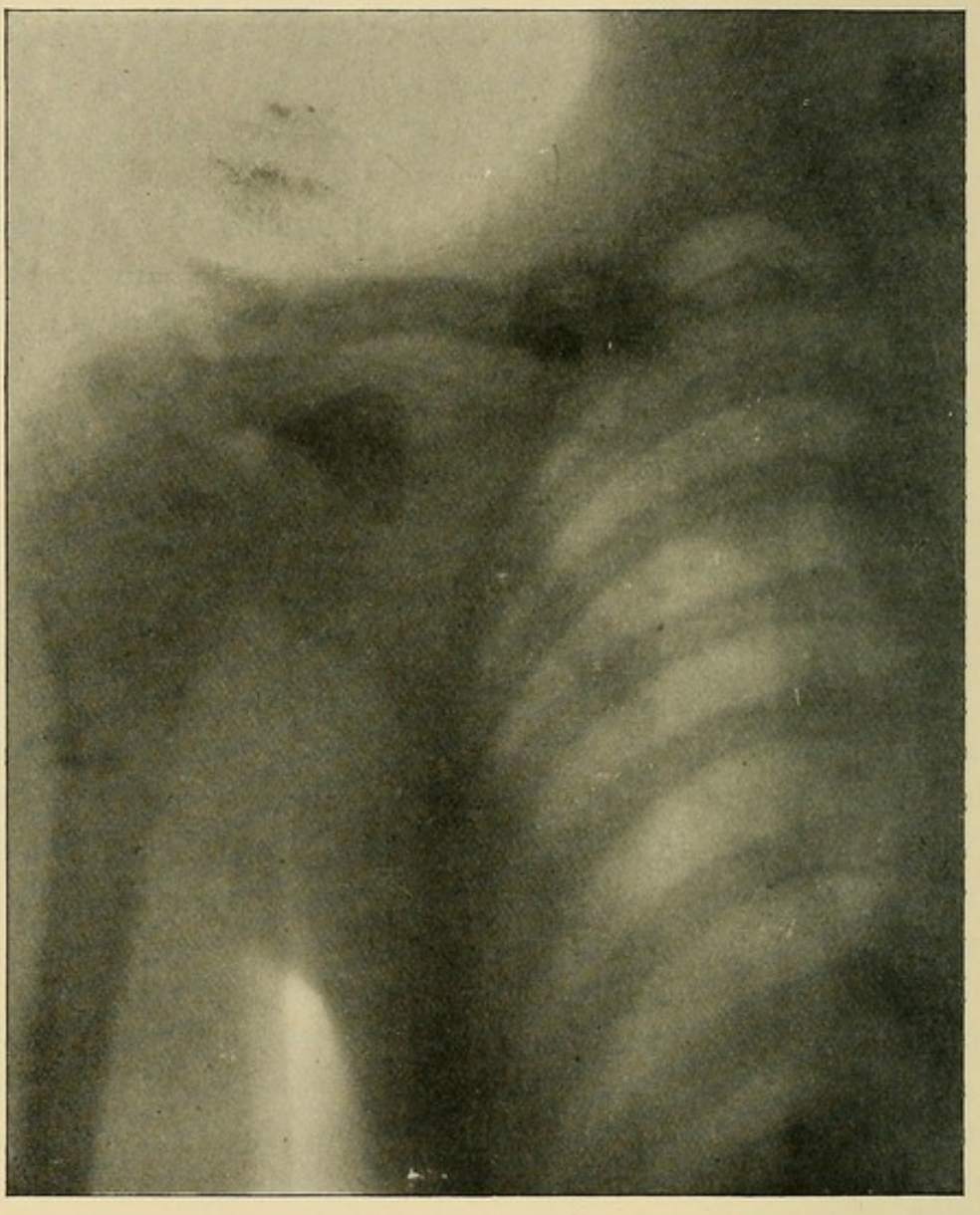


FIG. 66.—BULLET IN SHOULDER, LYING ON SCAPULA. FIRED FROM FRONT.
(Dr. Scott, *American X-Ray Journal*, July, 1899.)

above the insertion of the deltoid muscle. The bullet was removed by Mr. Anthony Bowlby.*

* For excellent illustration, see *Intercolonial Medical Journal of Australasia*, September 20, 1900, p. 452.

Fig: 67 gives a good idea of the record obtained from small shot. It was taken from the arm of a gentleman who had been accidentally shot twelve months previously. Two pellets lie close to the ulna, a small portion of which is portrayed. They caused no trouble, and as the patient was strong and muscular, their presence could not have been detected by any other means. In cases of this kind, where a foreign body has been embedded for a long period of time without giving rise to any inconvenience, it need scarcely be remarked that few surgeons would counsel removal.

The radiogram of a bullet-wound may help diagnosis in various

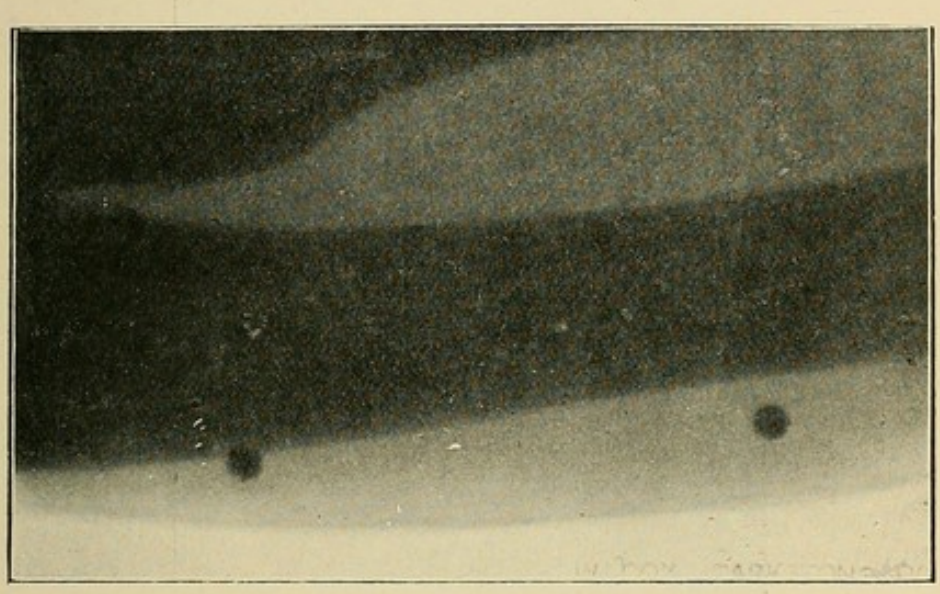


Fig. 67.—Shot embedded in Muscular Forearm (taken in 1897).

ways. In the following case, related by Dr. Mandras, of Paris, it threw light upon an injury of the kind long after its infliction :

'M. B—— was struck about fifteen years ago by a bullet from a revolver a little below the distal end of the dorsal surface of the first metacarpal. There was no fracture, but the ball glanced round the bone, and caused an extensive laceration of the tissues at the lower and inner part of the thenar eminence.

'Forty days after the accident the wound was healed, but there was complete loss of power of the thumb. Professor Dubreuil extracted a disc-shaped fragment of a bullet the size of a franc. Soon after a second piece, as large as a lentil, was taken away, followed by a third two and a half months later, but it was a year before the thumb regained its movements.'*

* 'Radiographie en Médecine,' par V. Mandras, M.D., Paris Thesis (Baillière, Paris, 1896, p. 28).

A radiogram of the hand by Messrs. Joubert and Bertin-Sans showed (1) a slight depression upon the metacarpal bone, doubtless due to the destruction of the periosteum by the projectile, and (2) the presence in the ball of the thumb of such metallic débris. By the courtesy of Dr. Mandras, the photograph is reproduced in Fig. 68.

Nimier and Laval* have published an interesting article upon

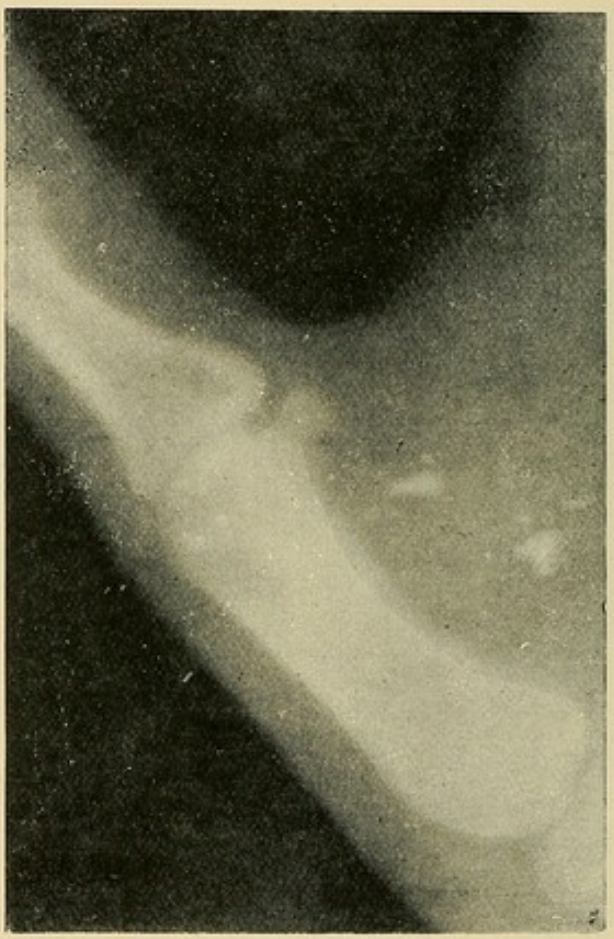


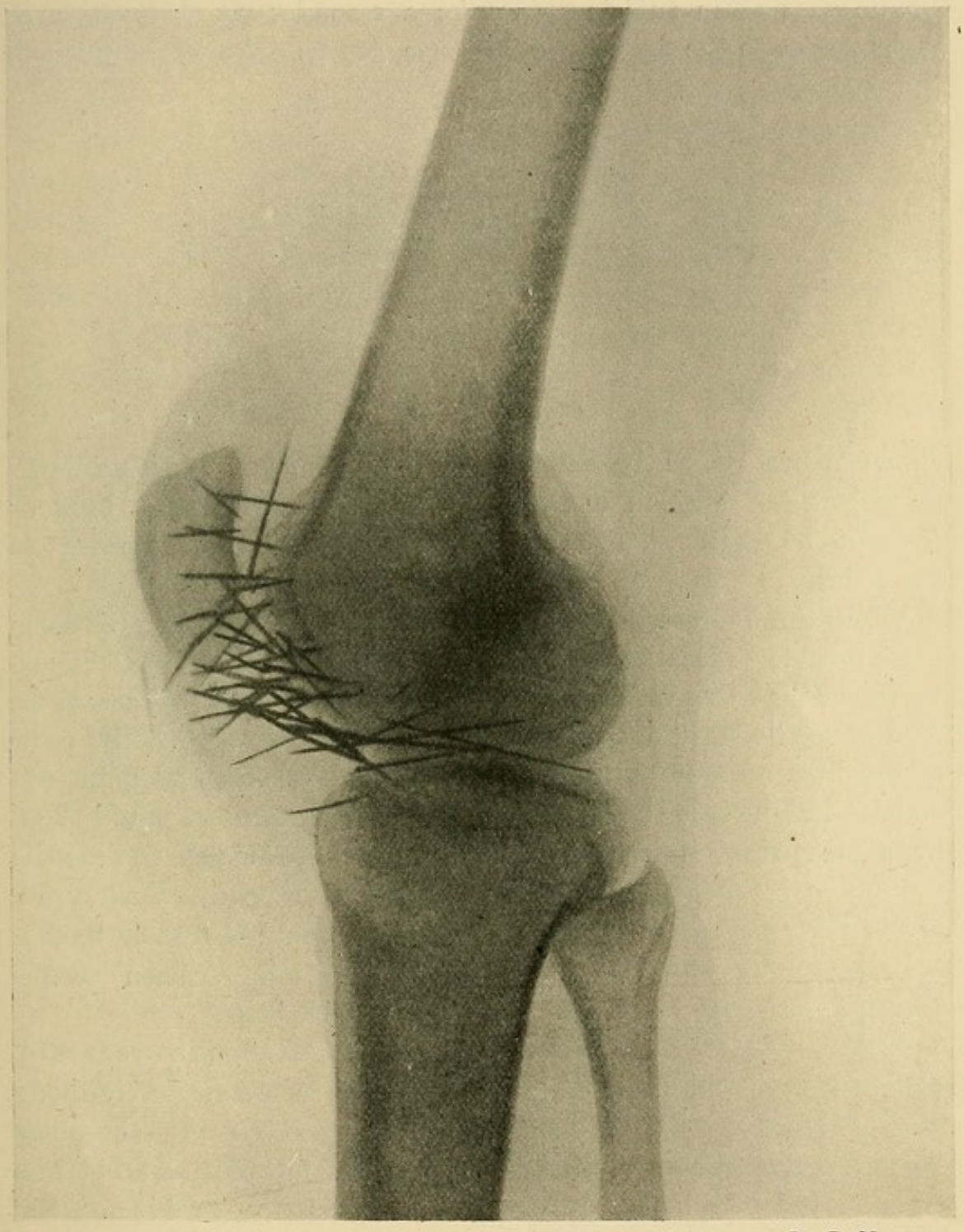
FIG. 68.—THUMB SHOWING LEADEN DÉBRIS AND ABSORPTION OF BONE (DISTAL END OF METACARPAL) AFTER IMPACT OF BULLET. (Mandras.)

The above print is from an *x*-ray picture taken direct upon sensitized paper, and presents a negative record, in contrast from the positive print obtained from an ordinary *x*-ray plate.

accidental poisoning due to the retention of lead missiles. They give an illustration showing a great number of No. 9 shot, many of them misshapen or reduced to fragments, scattered along the track of a wound between the knuckles of the hand and the lower half of the forearm. There appear to be some hundreds of pellets and metallic fragments. Abdominal colic, a blue line on the gums, and

* *Le Caducée*, Journal of Army Medicine, September 7, 1901, p. 53.

other signs of lead-poisoning occurred. Operation on the arm was followed by recovery, with good movement of the fingers.



Dr. D. Morgan.

FIG. 69.—NEEDLES IN KNEE-JOINT.
Mr. Robert Jones's case.

A most striking instance of the location of a packet of needles in and around the knee. This print has been kindly supplied by Mr. Robert Jones, F.R.C.S. (see Fig. 69).

Localization of Foreign Bodies.

In order to localize the exact position in the tissues of a foreign body, it is often sufficient to take a second x-ray observation at right angles to the first. For instance, let us take Fig. 69, which

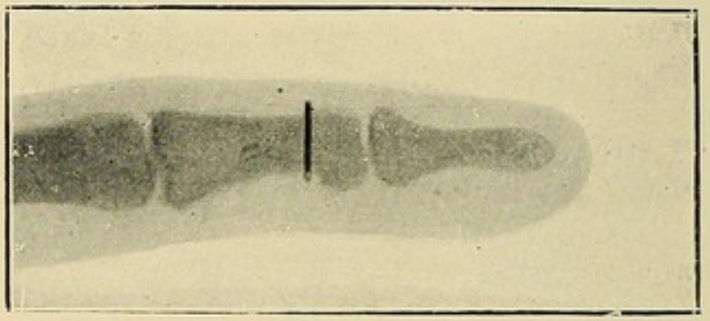


FIG. 70.—NEEDLE IN FINGER, SHOWING EYE.

shows a needle to be embedded in the finger. With so small an object, the surgeon has no clue as to whether it lies back or front of the digit. A cross-photograph, however, will at once settle the point.

When the fluorescent screen is used, the surgeon might in some cases be able to localize by means of acupuncture needles. Thus, he might take two views at right angles, and in each pass across the field a needle until it apparently touched the foreign body, or he might first accurately fix the shadow and push an acupuncture needle straight into the tissues in the direction indicated, and then, by a cross-view, ascertain the exact depth to which the needle should be carried. Such a proceeding would obviously be confined in its application to the less vital regions.

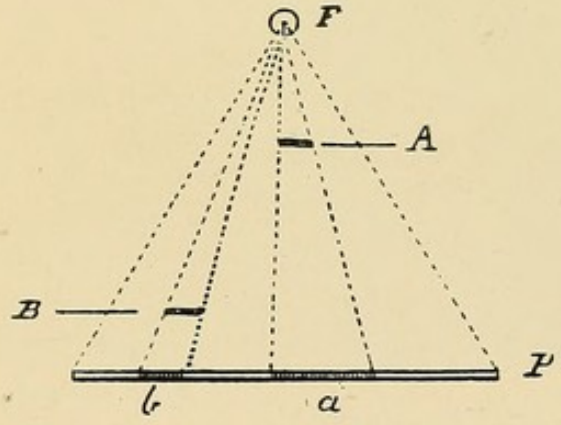


FIG. 71 (WALSH).

Other aids to the correct reading of the record of a foreign body are furnished by (*a*) the sharpness of the shadow outline, and (*b*) its size in relation to the original object. These points are both shown in the following experiment of Mr. Greenhill's. A radiogram was taken of a hand with two sections of bullets exactly corresponding in size, placed, the one on the back of the hand, away from the plate, and the other on the palmar side next to the

sensitive surface. The difference in the resulting images was striking. That of the lower one was clear, sharp, and almost of the same size as the original section; the other, on the contrary, was darker, larger, and more diffuse. This difference in the size of the recorded shadows is explained by the fact that the rays issue from the focus tube in radiating straight lines; the diagram (Fig. 71) will serve to show what is meant. Let F represent a focus tube in action, P the sensitive photographic plate, and A and B two objects of similar shape and size, such as two halfpenny pieces, but A being near the focus tube and B near the plate. It follows, then, as the Röntgen rays radiate in straight lines from F to P, that the shadow *a* will be larger than *b*, inversely to the distance of A and B from the focus tube. In fact, given the distance of tube from plate, and the size of the shadows, the relative position of the intervening objects could be determined by a simple mathematical calculation. Upon this principle, indeed, the chief localizing methods are based.

It need hardly be pointed out that the ordinary localizing signs and symptoms, such as pain, tenderness, swelling, dyspnœa, and difficulty of breathing or of swallowing, together with the history of the case, will retain their former value to the medical attendant. Such aids to diagnosis, however, are often altogether wanting, and it is then that the surgeon will call in the aid of the Röntgen rays. In short, the philosophical observer will find therein an additional means for conducting exact investigation into regions hitherto inaccessible to either direct or indirect visual inspection.

In practice, the location of an object buried in deep tissues or in the larger cavities of the body often presents peculiar difficulties. Suppose a bullet to be lodged near the surface of the lung, there would be a better chance of finding its exact position than if it were more deeply embedded. In investigating the brain, the photographic field is somewhat obscured, as the rays pass through a large mass of soft material and two surfaces of bone, of varying thickness and density, which under present methods are more or less recorded on the plate.

In the case of a foreign body in the brain, the action of a cross-record may be explained by the diagram on page 142 (Fig. 72):

Let *sk.* represent the skull; *f.b.* the foreign body; No. I. the lamp, and A the sensitive plate used for the first position; No. II. the lamp, and B the plate for the second position. Then the shadow A1 will fix the plane between No. I. and A in which *f.b.*

lies. The exact point of *f.b.* on that plane is determined by the shadow B2 on the second plate B, which fixes the plane of *f.b.* between No. II. and B. In other words, the foreign body lies at the point of intersection of the two planes obtained by the two radiograms taken at right angles the one to the other. In taking the second or cross photograph, the lamp should be placed at exactly the same distance from the plate as in the first exposure. It should also be over an exactly corresponding part of the plate, as, for instance, the centre. In dealing with an oval object like the skull, it will be better to leave the latter in one position and to move the lamp, placing the plate A on the table, and B at right

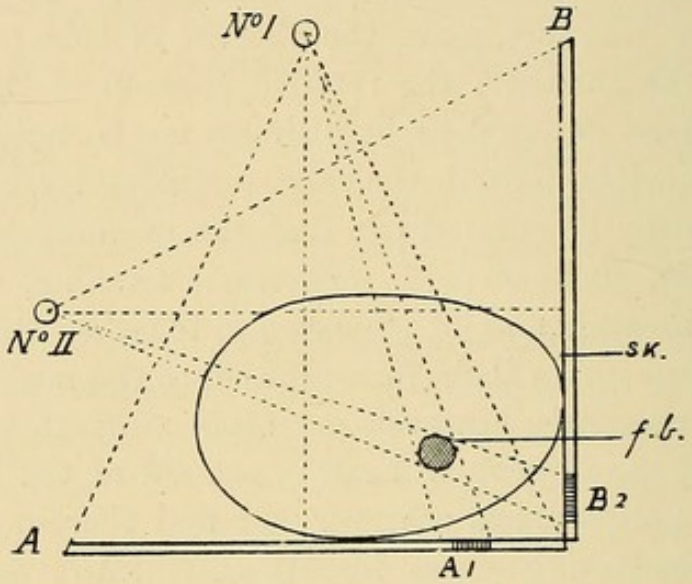


FIG. 72 (WALSH).

angles. In practice, however, the results are not so easily obtainable as might be inferred from the foregoing explanation. In the above case, for instance, there would be greater difficulty in penetrating the long axis of the skull, and a somewhat longer exposure would be needed for that position.

In one case, referred to on page 145, a bullet inside a skull was in the early days located by a cross or trans-frontal exposure of eight, and a fronto-occipital of twenty, minutes.

Another method, which takes both views in the short axis, is on the principle shown in Fig. 73. Two views are taken by shifting the focus tube, but the body to be penetrated and the sensitive plate remain in exactly the same relative positions. The lamp is put at the same distance from the plate in both views, and also in some known relation to a given point, say the centre or the edge of

the plate. By comparing the resulting shadows, a conclusion can be formed as to the intersection of the planes, 1a and IIb. This is the exact principle of the localizing apparatus devised by Mr. Mackenzie Davidson, who places threads on the lines between No. I. and *a*, and No. II. and *b*, and by shifting the focus tube takes two images on one sensitive plate.

Foreign Bodies in Brain.

By the kindness of Mr. Davidson the writer has been enabled to reproduce the accompanying illustration (Fig. 74), showing bullets artificially introduced into the head and neck of a

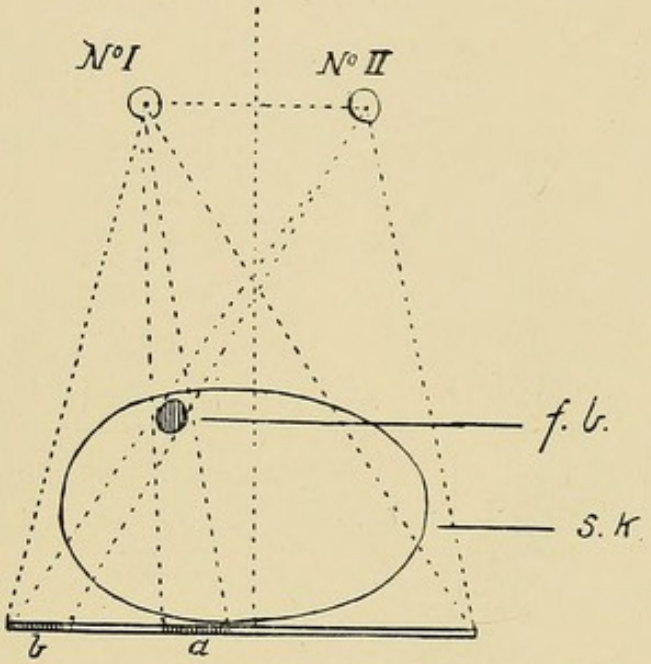


FIG. 73 (WALSH).

cadaver. Commencing from above downwards, the round ball at the top was placed in the right frontal lobe of the brain, and the conical bullet next to it also inside the brain, close to the right parietal bone. As the right side of the head was placed next the sensitive plate, both these bullets were brought close to the film, a fact which accounts for their clear definition. For a like reason their shadows in the original photograph correspond nearly in size with those of the foreign bodies. Their sharpness of outline is wanting in the third bullet (from above downwards), which was placed in the centre of the lower portion of the skull cavity, over the basilar process of the sphenoid. The radiographic record of the last missile, moreover, is larger than the original, owing to its

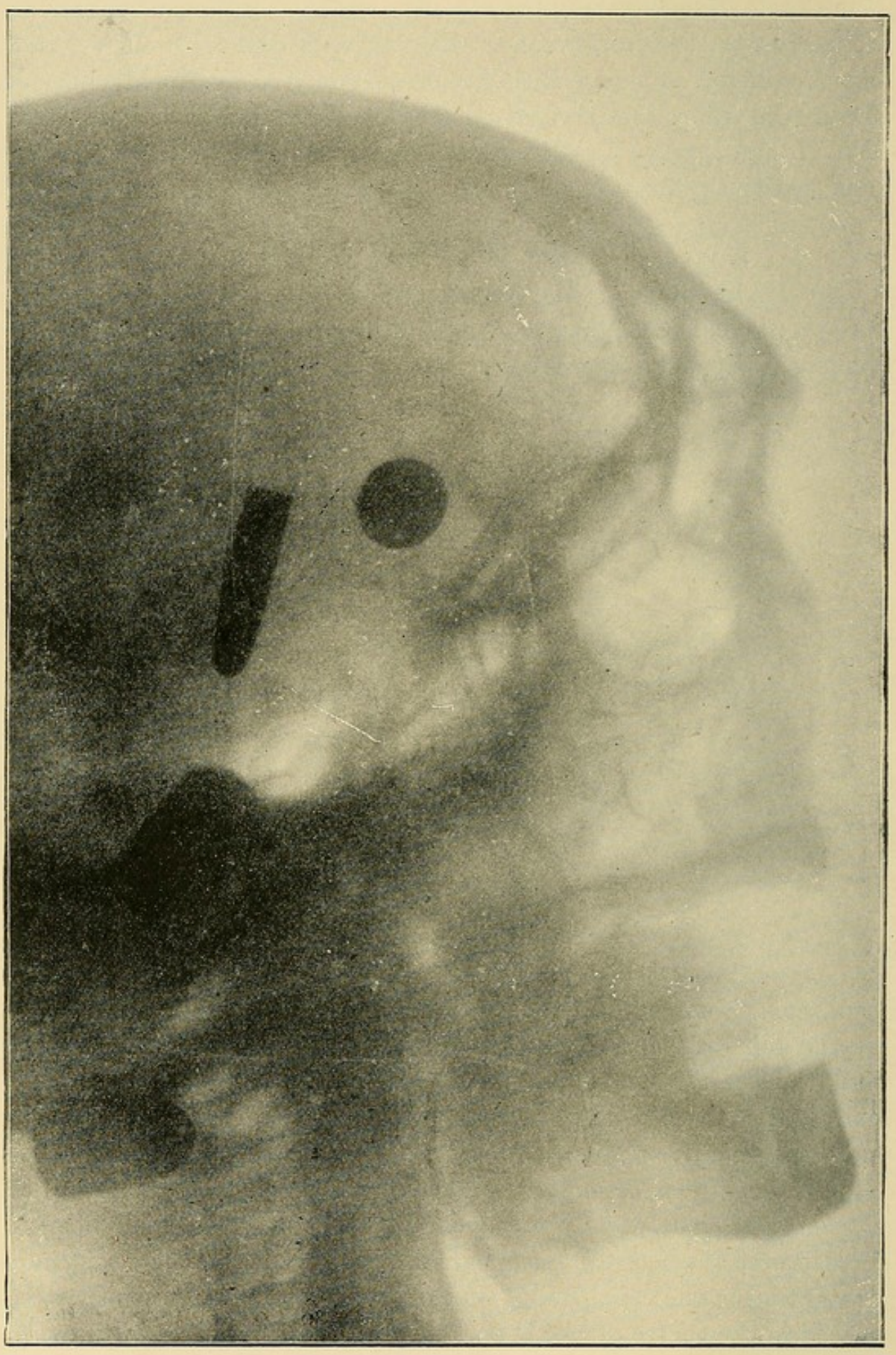


FIG. 74.—THREE BULLETS IN HEAD OF A CADAVER; ONE IN NECK; REDUCED ABOUT ONE-THIRD.

greater distance from the sensitive plate. Much the same may be said of the remaining bullet, which is deeply embedded in the middle line of the muscles of the back of the neck.

In the absence of definite information as to details, it may be conjectured that the tube, acting strongly from both a photographic and a penetrative point of view, was placed close to the skull, and that the exposure was fairly long. Under those conditions, the side of the skull next the lamp would be reproduced only faintly, if at all, and a reference to the figure will show that it represents mainly one side of the skull, namely, that next to the plate. It will be noticed that the frontal sinus is displayed, the gums are toothless, the tongue well defined, and, lastly, that the excellence of the result is to some extent accounted for by the thin bones, and the fact that the photograph was obtained from a dead subject.

An admirable instance of ingenious intracranial localization has been kindly furnished to the present writer by Professor Waymouth Reid, of Dundee. Owing to the shedding of hair that followed the first exposure to the Röntgen rays, he found it impossible to procure a cross-photograph. Although the plan he adopted does not stand comparison with more recent methods, it nevertheless has a distinct historical value; and the case itself presents features of great clinical interest, so that a short account may be here inserted:

The patient, a young gentleman, from whom the radiogram was taken, accidentally shot himself by a bullet from a revolver on May 21, 1891. He came under the care of Dr. Blaikie Smith, of Aberdeen, who published an interesting account of his case.* When found after the accident, blood and brain matter were oozing from a wound in his forehead, a little above and to the outer side of the right supra-orbital foramen. A director passed into the aperture of the frontal bone, and through the substance of the brain, reached somewhere near the upper extremity of the fissure of Rolando. With regard to the track of the bullet, Dr. Blaikie Smith remarked: 'It seems clear, from the position of the opening in the skull, that the missile penetrated the brain about the lower part of the first frontal convolution. Continuing its course obliquely upwards through the convolution, it apparently next entered the motor area of the brain, producing, as direct results, paralysis of the arm and leg on the opposite side.'

Strange to say, the patient recovered entirely from this serious

* *British Medical Journal* for September 17, 1892.

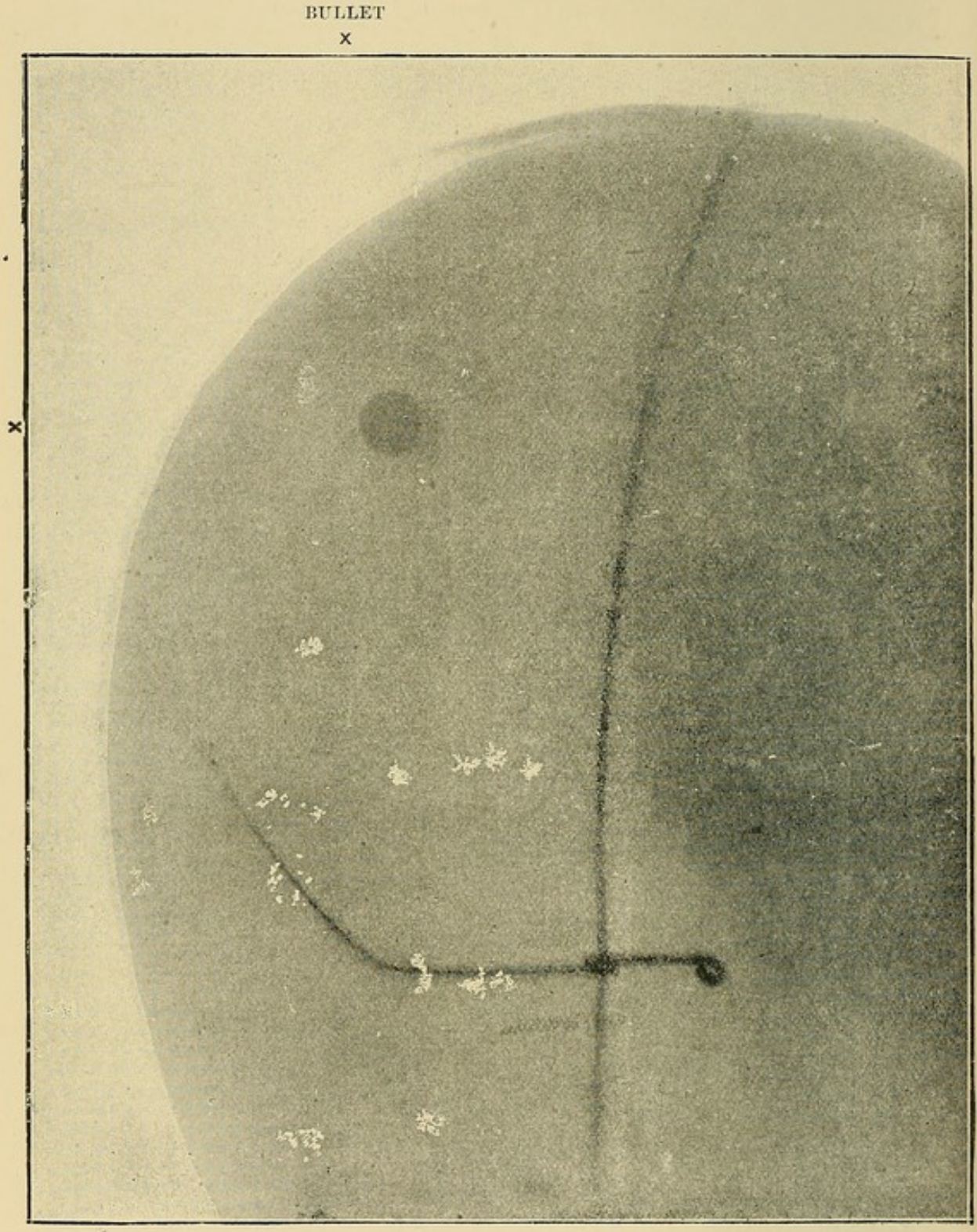


FIG. 75.—BULLET IN BRAIN (OR WITHIN SKULL) OF LIVING SUBJECT. LEAD WIRE CAGE USED FOR LOCALIZING.

Professor Waymouth Reid's case.

wound. Five years after the accident, at his own request, a Röntgen ray photograph, reproduced in Fig. 75, was taken by Dr. Reid. An external landmark was secured by means of a head-cage of leaden wire fitted to the side of the head, which was placed upon the sensitive plate. Further details need not be given here, but those interested in the point will find a full description in earlier editions of the present book.

Dr. Reid concluded that the bullet, after it had traversed the brain, came to a dead stop, flattened against the right inner surface of the skull, $1\frac{1}{2}$ inches above the Sylvian line, and $3\frac{3}{4}$ inches back from the vertical rising to the Rolandic line.

His highly ingenious—indeed, brilliant—*x*-ray diagnosis nearly confirmed that arrived at in the first place by Dr. Blaikie Smith. In his published account of the case, the latter wrote: 'In all probability, the bullet has become arrested either in the leg centre or in its immediate vicinity. The exact situation is open to doubt; *possibly the future may determine its position with greater accuracy than can be done at present.*' In the light of recent events, the remarkable passage printed in italics reads like an inspired prophecy. Dr. Smith, however, has explained to the writer that what he had in mind was the possible future development of localizing signs. He has added that when he last saw the patient the left knee-jerk was still exaggerated, and the left hand apt to become cold from slight causes, the latter result being perhaps due to trophic disturbances.

A somewhat similar case has been published by Dr. Fattic in an American journal.* A boy of nine was shot in the forehead—$\frac{1}{2}$ inch over the superciliary ridge, and 1 inch to the right of the median line—with a revolver bullet of small bore (32 calibre). The wound passed upwards, backwards, and slightly outward, but the missile could not be felt by a sterile probe passed in for a distance of $3\frac{1}{2}$ inches. Antiseptic irrigation and dressings were applied and shock overcome by free stimulation. The lad had complete paralysis of the left arm for a week, after which time he got gradually well. Seventeen months after the accident the bullet was located close to the frontal bone by two exposures—a trans-frontal one of eight minutes, and a fronto-occipital of twenty minutes. Dr. Fattic's explanation of the position of the foreign body may be gathered from the following note: 'From the history of the case it is evident that the motor area of the right side of

* *New York Medical News*, August 28, 1897.

the brain, controlling movements in the left arm, was injured, and the relief from the paralysis and the present location of the bullet, as shown by the radiograms, warranted the belief that the missile must have retraced its passage along the brain wound, assisted by the force of gravity.'

Another somewhat similar case has been recorded by Sir William Banks.* A lad of sixteen was accidentally shot with a pea-rifle at a distance of 2 feet, the bullet entering the skull at the root of the nose, slightly to the right of the middle line. He was insensible for a week, and then rapidly recovered his senses, but was completely paralyzed in the left arm and leg, and partially so in the face. At the end of six weeks the arm and leg were partially and the face wholly recovered. After several months his left leg was practically well, but the hand had not recovered the power of extension. He could close his fingers with a strong grip, but was unable to open them again. An *x*-ray photograph showed the bullet lodged in the cerebrum about an inch and a half in front of the occipital bone, and about one inch to the right of the middle line.

Professor Sherington was of opinion that the bullet had damaged the internal white capsule. He thought the missile would hardly have gone through the capsule, or the result would have been more permanent. Bruising of the capsule or pressure by blood-clot might have occurred. No disturbance of sight was present, although the bullet was lodged near the visual area. Operation was not considered advisable, on the ground that the bullet was probably encysted, and was doing no harm.

Messrs. Rémy and Contremoulin devised an ingenious method of localization, which was laid before the Paris Academy of Medicine on March 20, 1897. Having taken two radiograms by a Crookes tube in different positions, they were enabled by means of a geometrical figure to determine the exact position of a foreign body. Then, by a special apparatus, somewhat like the compass used by sculptors, they were able to fix with mathematical accuracy the depth of the object from the surface.

An interesting case, recorded by Max Scheir, was that of a man of twenty-seven, who had received a gunshot wound above the right superciliary ridge. From the symptoms it was imagined that the bullet had lodged in the orbit, which was explored, but without

* *Liverpool Medico-Chirurgical Journal*, March, 1902.

success. Five years later the rays revealed a foreign body somewhere near the Gasserian ganglion. A radiogram taken at the time would have prevented the useless exploration of the orbit. Moreover, had the bullet been removed by operation, the patient might have been spared the ensuing paralysis of the fifth (except its motor branch) and of the olfactory and optic nerves.

Many other bullets have been detected in the brain by the Röntgen rays.* Thus, Eulenberg described two such cases. In the first the foreign body was found in the right middle fossa of the skull, a little to one side of the median line; in the second it was shown close behind the orbital fissure. In detecting a bullet in this position, it is of practical importance to note that it may

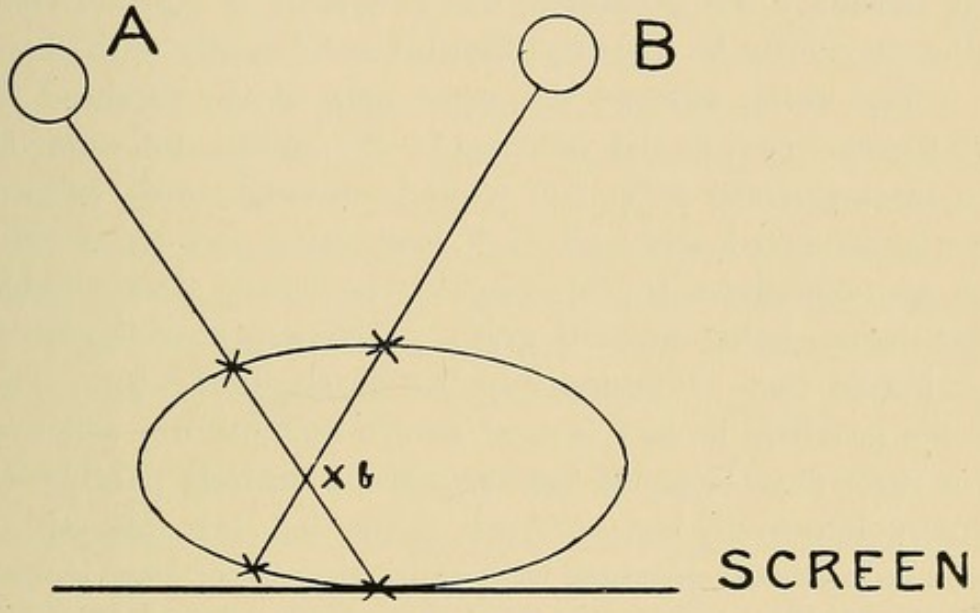


FIG. 76.

sometimes be readily seen by means of the screen where a long exposure has previously failed to obtain a photographic record, as in a case described by Dr. Bruce.† In such an event it is possible to locate with the tube in two positions (A, B) by bringing an opaque object into line with the foreign body, and then marking the entry and exit of that line on both sides of the skull. The point of intersection would be the site of the bullet.

In radiographing the skull short exposures are desirable, so as to lessen the chance of subsequent loss of hair from special susceptibility or from over-exposure.

If a prolonged screen examination, or more than two or three

* *Deutsch. Med. Wochenschrift*, August 17, 1896.

† *Medical Record*, April 17, 1897.

exposures have been made, it will be wiser to put off any further operations for a week or ten days.

The tube should be placed at a distance of 15 inches to 20 inches from the plate. The head may be fixed in a specially contrived rest, with the patient in the sitting posture (Mackenzie Davidson), or it may be held in a canvas sling, with the patient lying on his back, after the ingenious method devised by Mr. E. S. Caldwell.* For ordinary lateral exposures the simplest plan is to make the patient lie down and rest his head sideways on the plate.

An interesting case of the localization of eight fragments of a bullet in the brain was reported by Drs. W. W. Keen and W. M. Sweet, of Philadelphia.†

The patient, a boy of fifteen, was first seen in April, 1903. Six months previously he had shot himself accidentally with 22-calibre rifle. The bullet entered the right side of the forehead ½ inch above the eyebrow, at the junction of the middle and outer thirds. Brain matter oozed from the wound; several small splinters of bone were removed, and a sliver of lead was found under the skin, about an inch above the opening in the bone. The weight of a similar unused bullet was 29½ grains. The weight of the sliver was 5½ grains, so that 24 grains were to be accounted for. The day after the accident he had several severe epileptiform seizures, and two or three days later the left leg became entirely paralyzed. He gradually improved, but on April 9 the left leg was still weak, showed an unsteady balance, with some increase of knee-jerk.

Dr. Sweet then made skiagraphs of the head and localized the fragments by his method, an account of which will be found in the article referred to. The following facts were disclosed: 'In the brain there are one principal fragment and seven other minute fragments of the bullet, the largest of the latter being about the size of a medium-sized pin's head. Two of these fragments are at the point of entrance. Five of them are scattered through the brain, 2·5 centimetres to 3 centimetres *above* a line running from the wound at entrance to the present position of the ball. The position of each one of these fragments was precisely indicated on the scalp by Dr. Sweet.

Upon this information Dr. Keen decided not to attempt removal

* 'Röntgen Rays in Therapeutics and Diagnosis,' Pusey-Caldwell (Saunders, New York, 1903, p. 172).

† *American Journal of the Medical Sciences*, July, 1903, p. 1 *et seq.*

of the ball. With a view to accurate determination in the future of any change in the position of the ball, he excised two small spots, including the hair follicles from the scalp, so as to leave two permanently bald spots at the points indicated by Dr. Sweet. The relation of the ball to the ventricle was next ascertained by making a vertical section through a brain hardened in formalin as nearly as possible in the plane of location. This was compared with Dalton's vertical transfused sections.*

In this way he located the ball just above the ventricle and far below the leg centre. The inference was that the bullet had struck the cortex at the leg centre and had rebounded, or otherwise reached its secondary position. That view was strengthened by the fact that the small fragments lay above a direct line from the point of entry to the position of the embedded ball. Further, if the ball had gone straight to its present position the leg centre would not have been touched at all. Dr. Keen decided that any attempt to remove the bullet would cause more injury to the brain than the bullet did in its then position. The patient was sent home, with directions not to study much for a year. Immediate operation was advised in the event either of an epileptic fit or of severe headache or other symptoms suggesting cerebral abscess.

Gunshot Wound of Brain.

An interesting case is related by Borden† of a private soldier who, on March 27, 1899, was shot in the head by a Mauser bullet, which entered an inch above the supra-orbital ridge slightly to the left of the middle line. The foreign body was found by the Röntgen rays to be lodged in the left occipital lobe. Six months after the injury his general condition was good. He suffered pain at times in the lumbar region and in front of the left parietal eminence. There was no loss of power on either side, but some weakness in right arm and legs and a slowness in response to mental impulse. No epileptiform seizures, no disturbance of nutrition or bodily functions. The patient afterwards entered the mail service, and returned to Manila on duty.—*Reported by Major A. C. Girard, Surgeon U.S.A. Army.*

Foreign Body lodged in Spine.

Dr. Phelps, of New York, has reported a case where a revolver bullet struck the thyroid cartilage, and, after passing through the neck, lodged in an unknown part. A radiogram showed a dark spot in the fourth cervical vertebra, and with the knowledge thus

* It corresponded with Plate XV. of Series C exactly.

† 'Röntgen Ray in Spanish-American War.' For full details of this case, see p. 42.

gained the surgeon was enabled to operate successfully. The ball first struck the hard lamina of the vertebra and flattened out, after which it barely penetrated the canal. Recovery was uneventful.

Mr. R. Clement Lucas localized by the *x*-rays, and subsequently removed a bullet from the front of the second cervical vertebra. The case was reported in the Surgery Section of the British Medical Association at Portsmouth on August 2, 1899.

Gunshot Injuries of Spine.

Borden* relates two cases of bullet injury to the spinal cord. In both instances a radiogram showed that the missile lay outside the spine.

'CASE 12.—*Gunshot injury of the cord; Mauser bullet lodged in back; localization by Röntgen ray; removal; discharge for disability.*

'C. J. E., private, wounded at Malate, Philippine Islands, June 31, 1898. Bullet entered at a point over the middle of the left deltoid muscle, opposite the surgical neck of the humerus. At the time of the casualty the arm was deflected from the thorax at an angle of about 60 degrees. There was no wound of exit. Immediately upon receipt of the injury the patient fell to the ground, and there was complete paralysis, involving both the upper and the lower extremities. He was removed to the hospital, soon became unconscious, and remained so for two days. There was no discoverable active hæmorrhage or fracture. Reflex functions, so far as it was possible to ascertain, were entirely absent below that portion of the spine where the injury was supposed to be. There was rectal and vesical paralysis. After an interval of three weeks, during which time there was no improvement, he began to regain control of his arms. A progressive change for the better was inaugurated, followed by partial restoration of power of movement. Complete sensibility, both as to pain and temperature, returned to the right half of the body. He was transferred to the Division Hospital, Presidio, San Francisco, October 22, 1898. At that time he was able to walk, though with great difficulty. On his arrival at Presidio there was a loss of electro-contractility, as of sensibility, in the left arm, forearm, and hand, left half of the thorax, left half of the abdomen, and left leg and foot. There was loss of sense of temperature over this area. Tractile sense, however, was generally present. A partial paralysis of the sphincters ani and vesicæ persisted. Knee-jerk increased on right side, feebly present on left side. Motion of the extremities was almost completely restored. Symptoms in reference to the brain negative. Sexual power and desire almost nil. No ankle clonus. No irregularity in any of the internal organs, but a languid and sluggish condition, lacking the power of vigorous action.

'January 2, 1899: Motion now only slightly impaired in left upper and left lower extremity. Co-ordination of muscles virtually normal. Power of muscles is inhibited in right leg. Electro-sensibility absent in left lower extremity, extending from the crest of the ilium to the plantar surface of the foot. There is also loss of the sensation of temperature over this area. Sensibility completely absent in left leg and foot. Mobility absent in left foot. Micturition and defæcation disturbances are still present. Sexual power is diminished, but

* 'Röntgen Ray in Spanish-American War,' p. 40 *et seq.*

desire is normal. As far as he can remember, there has been a constant dull pain in the back in the region of the third intercostal space, an inch and a half to the right of the spinous process of the third dorsal vertebra. A radiograph shows a lodged Mauser bullet at the point where the pain above mentioned exists. Bullet was extracted March 7, 1899, and, as the patient remained disqualified for military service, he was finally discharged on account of impairment of mobility of right leg and thigh and loss of sense and contraction of the left leg.'—*Case reported by Major W. S. H. Matthews, Surgeon U.S. Volunteers.*

Foreign Bodies in Neck and Thorax.

Such objects as coins and buttons have been detected in the larynx, bronchi, lungs, mediastina, and pleura by means of the Röntgen rays. In most of these sites, however, it is likely that the clinical signs and symptoms will afford an equally ready means of diagnosis.

Marcus and Boisson* reported to the French Academy of Medicine a case in which a bullet was located and removed from the hyoglossus muscle by the *x*-rays. After the operation a hysterical hemiplegia disappeared.

Dr. Walker Downie, of Glasgow, found a pin which had slipped into the larynx from the mouth. The foreign body could not be seen by the laryngoscope, but the patient, a boy, complained of 'a pinching pain at the back of the throat, and some pain in swallowing.' The pin was discovered by the rays, and easily extracted by external operation.† Dr. Downie has kindly allowed the accompanying reproduction (p. 154) of his original photograph. It was taken in early days by an exposure of eight minutes with an Apps coil having a 10-inch spark.

The plate shows parts of upper and lower jaws, with some of the molar teeth and their fangs. To the left are several of the cervical vertebræ, and in front, under cover of the lower jaw, is the hyoid bone, below which a light perpendicular band indicates the position of the larynx and trachea, structures which are particularly translucent. Crossing this light area, at the level of the lower border of the body of the fourth vertebra, is the pin with the head anteriorly, corresponding to the outline of the thyroid cartilage, and with its point apparently embedded in the cartilaginous disc between the fourth and fifth cervical vertebræ. The pin appears at least $\frac{1}{4}$ inch longer than the antero-posterior diameter of the larynx, and it is bent near the middle, with the convexity directed upwards.

* *Gaz. des Hôp.*, September 22, 1898.

† *Edinburgh Medical Journal*, January, 1897.

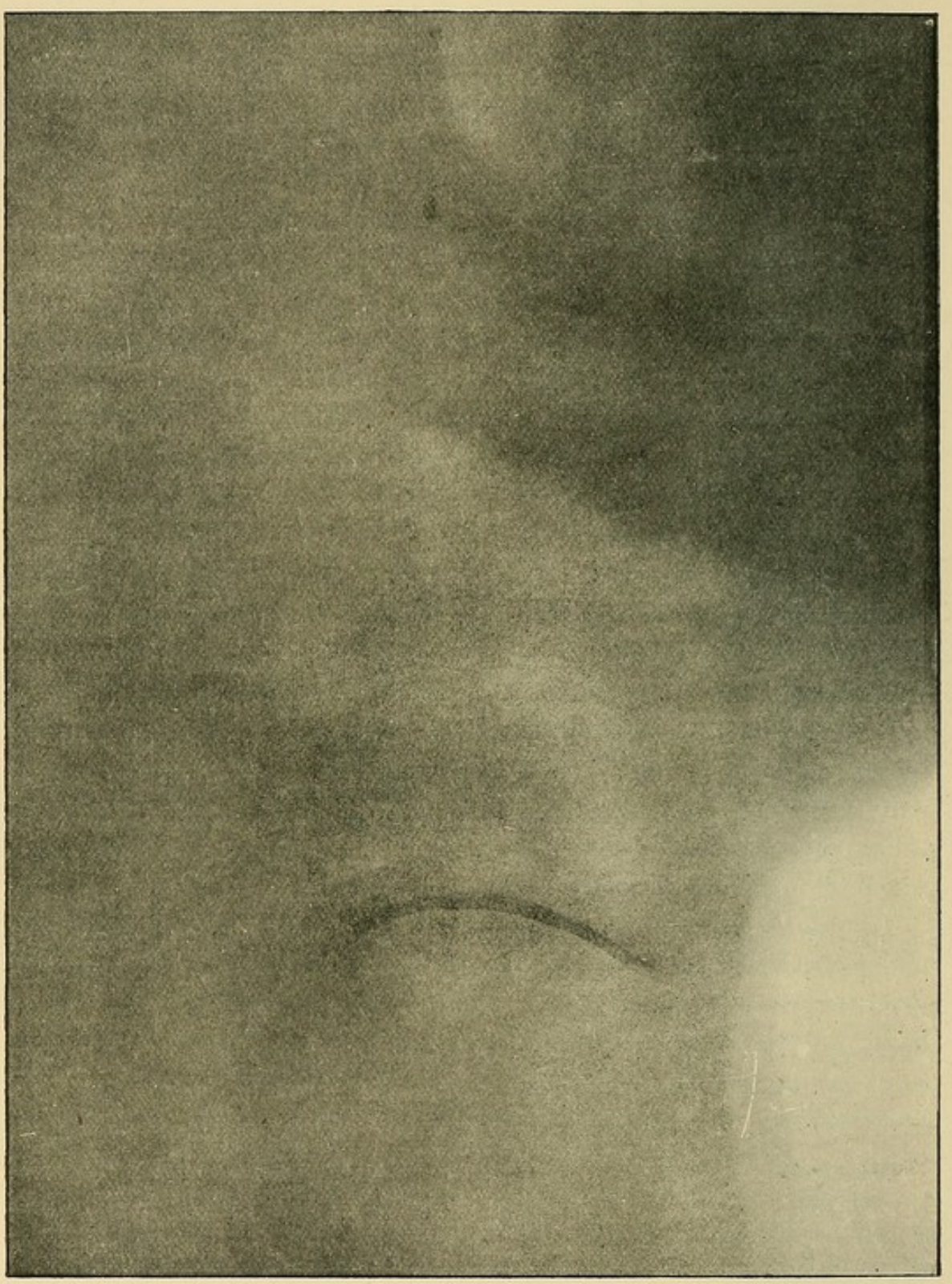


FIG. 77.—PIN IN LARYNX.
D. J. Mackintosh, M.B.

In an antero-posterior radiogram the pin was localized by means of two pieces of silver wire fastened with sticking-plaster, the one in the middle line, and the other at right angles in a carefully noted position. In the picture the two wires were shown fixed to the skin, and $\frac{11}{16}$ inch above the horizontal one was the image of the foreshortened pin, with the head close to the middle line, from which point the body of the pin was directed upwards and backwards. It is interesting to note that there was no indication of the vertebræ, through which the rays must presumably have passed to give the image of the pin shown in the photograph. That result was doubtless due to the high penetrative action of the focus tube, as well as to its nearness to the spine.

The principle of localizing by means of wires is capable of extensive application. Soft lead wire is suitable, and may in many cases be twisted round a limb. If fastened on with ordinary sticking-plaster, it should be remembered that most forms of that material are opaque to the rays, owing to the contained lead.

Dr. Downie has reported another case in which a pin was localized outside the larynx in a line behind the right thyroid cartilage, and removed by forceps.*

The beginner will do well to study all the figures attentively. In this way he will train his eye to the recognition of various objects, and will also prepare himself for the more difficult task of reading the fluorescent screen. Unfortunately, there is a loss of detail in almost any kind of reproduction for book illustration This is especially the case when the original radiogram is reduced on the block.

A Nail in the Trachea.

Dr. Garel† reported the case of a child aged twenty months who swallowed a nail 2 inches long, which was thought to have passed into the stomach. Some time after, as the child was getting thin, and a radiogram showed the foreign body to be in the windpipe, the nail was removed by a powerful electromagnet through a tracheotomy incision.

Thorax.

An indiarubber drainage-tube, when lost in the pleura, may now and then be located by the rays. However, as a rule it will yield

* *British Medical Journal*, October 22, 1898, p. 1243.

† *Thérapie*, D. Gevenwart, June, p. 250.

no readable record, falling as it does within the uncertain region of faint soft tissue shadows.

There is doubtless a great field of future usefulness for the Röntgen processes in lung surgery. That fact is well illustrated in a case published by Dr. White, of Pennsylvania.* 'I have now under treatment,' he writes, 'a young lad who accidentally shot himself with a 22-calibre parlour rifle. The ball entered the wall of the right chest on the mid-axillary line in the sixth interspace. The muzzle of the rifle was pointing upward. The patient complained bitterly of pain under the upper border of the right scapula. The history of the case and all the clinical phenomena would have led to exploration in that region, but the radiograph shows the bullet in the lower lobe of the lung, on a level with the tenth rib, and near the middle line of the body. The picture also shows in a convincing manner a pulmonary area (corresponding to the lower lobe) of increased opacity, and evidently the seat of blood-effusion and inflammation. The patient has all the clinical symptoms of a traumatic pneumonia.

'There can be little doubt that the difficult decision between operative interference and expectancy in penetrating gunshot wounds of the thorax without wound of exit will be greatly facilitated in the future by the accurate localization of the bullet.'

In some instances, from the penetrable nature of the foreign body —*e.g.*, a cherry-stone—in the pulmonary air-passages a radiogram cannot be obtained. The surgeon may, nevertheless, find valuable indirect evidence in the lessened excursion of the diaphragm on the affected side as shown by a screen examination.

In the œsophagus it is fairly easy to locate false teeth and other objects opaque to the rays. Thus, a London medical journal† commented on a case where the results of such an attempt, although negative, were nevertheless of an instructive nature. The facts were briefly as follows: A young lady swallowed by accident a set of false teeth. She called in a medical man, who, failing to remove the impacted plate from the gullet, pushed it, or thought he pushed it, down into the stomach. Some time later she went to a hospital, complaining of pain in the abdomen, and that region was radiographed, but without result. Shortly afterwards she brought up a quantity of blood, and was taken to another hospital, where she

* *The American Journal of Medical Science*, January, 1898, p. 4.

† *Medical Press and Circular*, January, 13, 1897.

died while an attempt was being made to radiograph the abdomen, to which pain was referred to the last.

Post-mortem it was found that the plate had lodged in the œsophagus below the bifurcation of the trachea, whence it had ulcerated into the aorta. This case suggests the advisability of examining the thorax at once by means of the rays whenever a person has been unfortunate enough to swallow a dental plate.

The late Dr. Blacker reported the following case: 'A. B——, æt. forty-eight, male. Swallowed set of false teeth consisting of plate and eight teeth, seen in lateral view between the levels of the cricoid and thyroid cartilages, immediately in front of the bodies of the vertebræ, and in the antero-posterior view from behind as a semicircular object, with the convexity to the right side of the vertebræ, about 2 inches in length.'*

In perhaps nine out of ten cases impaction of a foreign body in the œsophagus takes place at the second anatomical narrowing—*i.e.*, behind the manubrium on a level with the cross found on the radiogram by the shadows of the clavicles and the vertebral column. Less often it is lodged behind the cricoid cartilage. When found in the thoracic œsophagus, that position probably in all cases results from the foreign body having been pushed downwards. This last observation bears out the dictum that the use of a bougie or probang under such circumstances is not only useless, but also dangerous. Indeed, it is doubtful whether the use of instruments is warranted only in an emergency where *x*-ray methods are not available, as, for instance, in a remote country district.

If a foreign body be found impacted in the upper part of the gullet, the surgeon may decide forthwith to perform an œsophagotomy. Indeed, it is chiefly on account of the difficulty of localizing such objects that this operation has been hitherto of rare occurrence. As in the foregoing instance, where a foreign body is impacted in the gullet, the occurrence of gastric pain is apt to be misleading. Dr. Macintyre has described a case where a boy swallowed a half-penny some six months previously. The fluorescent screen showed the coin to be lodged opposite the third dorsal vertebra. In that instance the pain was constantly referred to the stomach. Indeed, where pain in that region cannot be explained by some obvious cause, the surgeon will do well to make *x*-ray examination of the chest a routine practice.

* St. Thomas's Hospital Reports, 1897.

One of the earliest radiograms of a coin impacted in the œsophagus was brought forward at the Clinical Society of London on June 22, 1897, by Mr. Bowlby. The patient, a boy, three and a half years of age, was under the care of Mr. Howard Marsh. He had been under

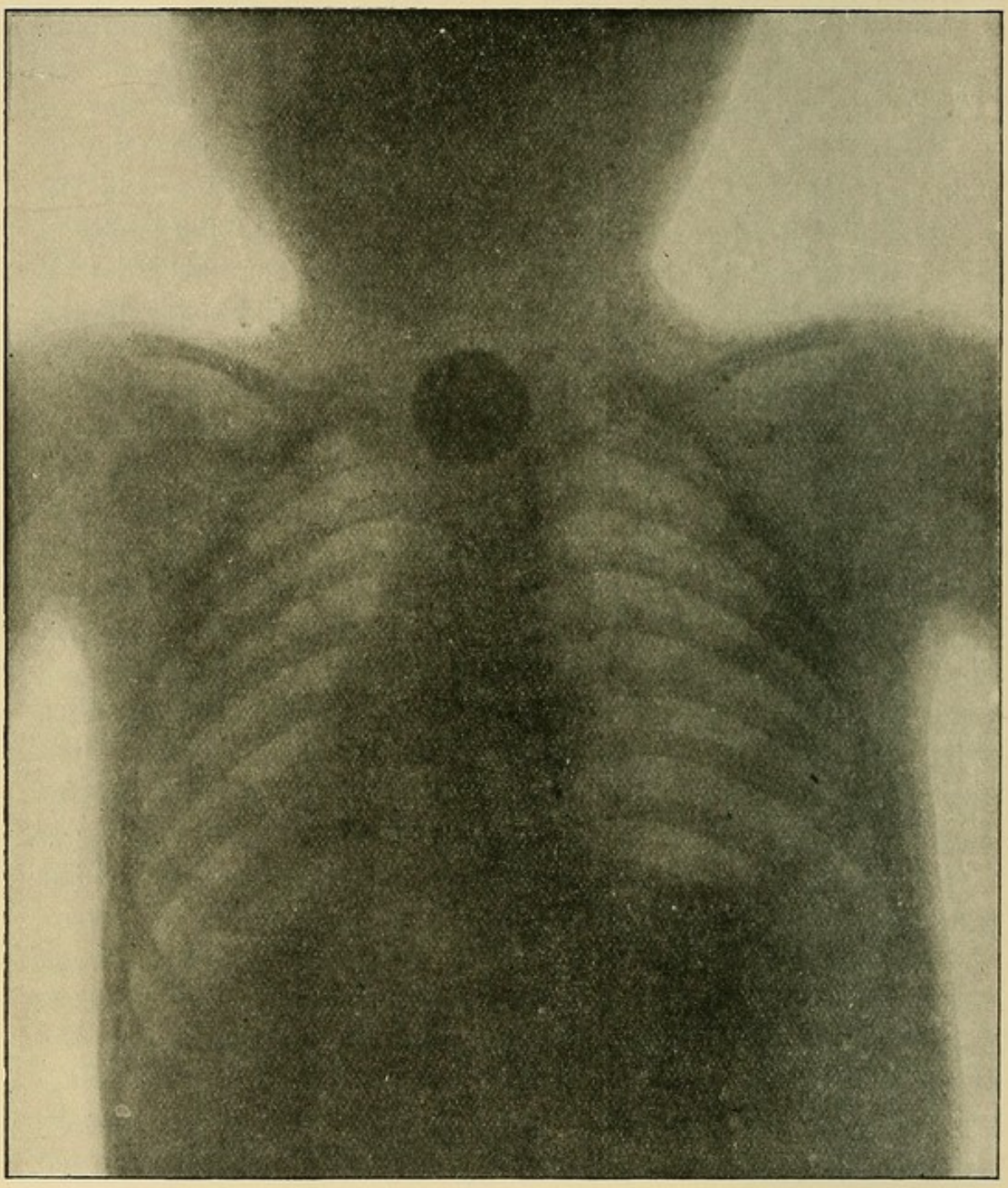


FIG. 78.—COIN IN GULLET.

observation for five weeks, during which time he showed no symptoms beyond occasional sickness. A radiogram taken by Messrs. Allen and Hanbury (Fig. 78) at once revealed the presence of the coin, a halfpenny piece, lodged in the gullet at the level of the second

dorsal vertebra. Removal was ultimately effected by means of a catch carried within a gum elastic catheter.

Dr. Mayo, of Rochester, U.S.A.,* has reported a case where an open buckle was shown by the radiograph to be impacted in the gullet of an infant. The buckle lay behind the upper part of the sternum, with its teeth projecting upwards and to the right. A left œsophagotomy enabled the surgeon to remove the foreign body by means of a bent probe. The chief point of interest was that the position of the teeth would have effectually prevented the pulling upwards of the buckle. The danger of attempting extraction by curved forceps would obviously have been great.

Professor White, of Pennsylvania, had a child, two years and five months old, brought to him with an obscure history of dysphagia and vomiting. The Röntgen rays showed a cruciform toy known as a 'jackstone,' impacted in the œsophagus on a level with the space between the second and third dorsal spines, a little above the bifurcation of the trachea. The object was in the shape of a Maltese cross, with an additional bar at right angles through its centre. As it could not be extracted by the mouth, gastrotomy was performed, and the 'jackstone' drawn down into the stomach and removed.

Mr. George Heaton, of Birmingham, has recorded† two interesting cases of coins that had been impacted in the gullet for a considerable time, but gave little evidence of their presence. In one case the foreign body had been swallowed three months, and in the other forty days previous to detection by the rays. One patient took solids and fluids freely, the other fluids only.

Among numerous other instances, the following may be selected: Dr. Bliss‡ found an iron staple an inch long, with two sharp points, so fixed in the gullet that the use of a probang would have still further impacted the foreign body. Removal could not be effected by curved forceps until the exact position of the staple and the direction of its points had been localized by means of the Röntgen rays.

In this class of cases the importance of the Röntgen rays can hardly be overestimated. As every surgeon knows, the difficulty of locating is often extreme. Undetected foreign bodies in the gullet

* *North-Western Lancet*, March, 1897.

† *British Medical Journal*, June 4, 1898, p. 1449.

‡ *International Medical Magazine*, March, 1897.

have been treated for pulmonary phthisis, croup, catarrh, asthma, and so on. Wallace of Edinburgh has recorded a case where a plate bearing six artificial teeth could be located only after repeated negative attempts with the œsophageal olivary bougie and 'coin-catcher.' A low œsophagotomy proved a failure, and gastrotomy was finally required.

Segond* removed a toothplate successfully by left external œsophagotomy. The foreign body was located by the rays at the level of the interclavicular notch. The plate had a metallic hook which ran into the wall of the gullet, so that the foreign body 'required considerable location' before it could be dislodged.

A lady's hat-pin was demonstrated in the gullet of an infant aged fifteen months under Mr. Ballance at St. Thomas's Hospital. It was lodged at the lower end of the œsophagus, the head being about the level of the cardiac end of the stomach. The pin was removed by a small incision in the stomach wall.

A most interesting case of removal of a toothplate from the œsophagus of a lunatic patient has been recorded by Dr. Nathan Raw.† The foreign body was seen with the fluorescent screen to be lying at a point a little below the upper end of the sternum, apparently fixed transversely across the gullet. An hour's patient trial with the forceps failed to remove the foreign body. With the aid of the screen, however, a long forceps was guided down to a projection of the plate, which was extracted with the use of considerable force. The patient lost a good deal of blood, but made a good recovery.

Holznecht‡ has reported a case in which a patient swallowed a set of artificial teeth on a plate during sleep. A Röntgen photograph failed to detect the foreign body. A few days afterwards it was detected by a screen examination lying in the œsophagus, just where the latter passes through the diaphragm. The pulsating object could be seen through the heart, and during the act of swallowing was observed to rise about an inch.

One practical point may be noted here, namely, that it is well to use the screen immediately before operation. One case is on record in which a French surgeon performed œsophagotomy for a coin that was found to have passed into the stomach.

* *Lyon Médicale*, August 5, p. 490.
† *Liverpool Medico-Chirurgical Journal*, September, 1901, p. 345.
‡ *British Journal of Dental Science*, January 15, 1901.

Bullet in Heart.

Mr. E. W. H. Shenton* relates the case of Max Meyer, who was shot in the heart two and a half years ago. The bullet could be seen with a screen moving synchronously with the beats of the left ventricle. From the absence of cardiac symptoms it appeared probable that the bullet was encysted in the muscular substance of the heart. The interesting point in connection with the screen examination was the extraordinary excursions made by the piece of lead under the influence of the cardiac and respiratory movements.

Foreign Bodies in Abdomen.

So far as the abdomen is concerned, coins and other foreign bodies have been located in the case of children. The importance of exact information of this kind will be at once recognised by those who are familiar with the needs of abdominal surgery. The results of ray work, when applied to the abdomen in adults, are apt to be disappointing, and depend on the photographic plate, as screen work is of little use in this region. However, a good definition of intestines and other abdominal organs can be procured in the case of small lower animals, and also of children. In the face of such facts it may be anticipated that it will be one day possible to obtain satisfactory radiograms of most of the abdominal viscera in the adult human subject. From time to time different experimenters have obtained an obscure record of intestines. The present writer has such a photograph taken in the summer of 1897, which shows a faint, but discernible, tracing of colon, of loops of small intestine, and of the sigmoid flexure of the rectum. The patient had signs of chronic intestinal obstruction. On the chance of localizing the lesion, he was given bismuth in 10-grain doses thrice daily for over a week before the abdomen was examined by the rays. Sometimes a loop of intestine is thrown into relief either by being distended with air, or from some peculiarity of its contents. With a stereoscopic picture a good effect is now and then obtainable.

The advantages of localization of foreign bodies in the intestines of adults need hardly be pointed out. Numerous possibilities will readily occur to the mind of the medical reader, such as the detection of a forceps or other instrument inadvertently sewn up in

* *Medical Electrology and Radiology*, January, 1904, p. 18.

the abdominal cavity. The passage of a Murphy's button through the bowel has been repeatedly demonstrated. The knowledge of the progress of a foreign body through the intestinal canal not only guides the surgeon in his prognosis, but also affords relief to the anxiety of the patient and his friends. For instance, a

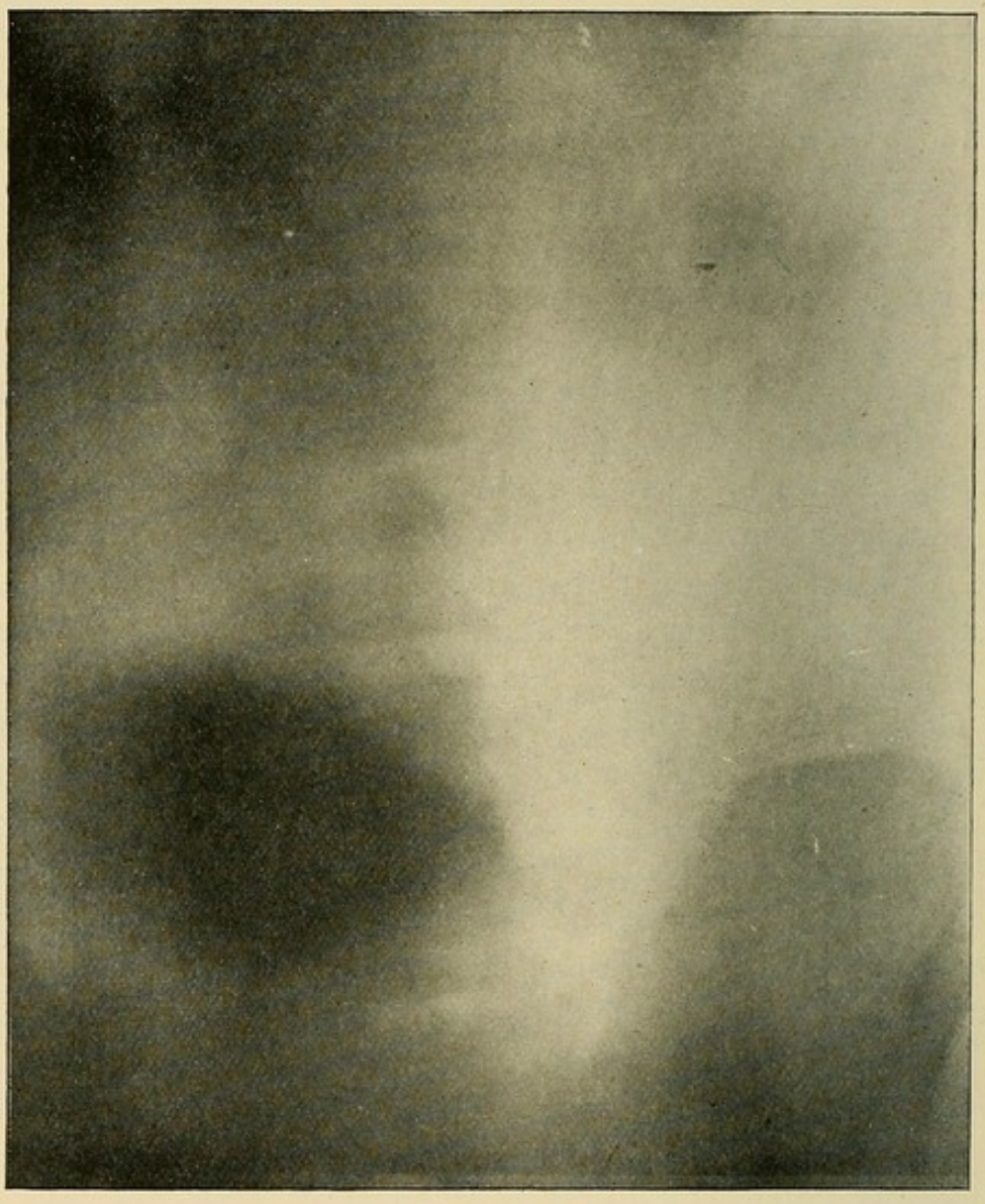


FIG. 79.—STOMACH OF 'OSTRICH MAN' DISTENDED WITH A MASS OF METALLIC ARTICLES AND GLASS, WHICH CAUSED HIS DEATH (*American X-Ray Journal*, July, 1898).

young lady was brought to the writer to be radiographed. She had swallowed a pin six days previously, and had taken purgatives freely for several days. She then grew alarmed, and consulted a medical man. The radiogram showed a pin apparently about midway in the ascending colon, and a prognosis of speedy passage

was made. In this case the finding of a pin in the abdomen of a well-nourished girl of nineteen must be regarded as a fortunate result.

Foreign bodies can be detected in the pelvis, either in the rectum or the bladder. Calculi in this and in other parts of the abdominal cavity will be discussed in another part of the book (see p. 172).

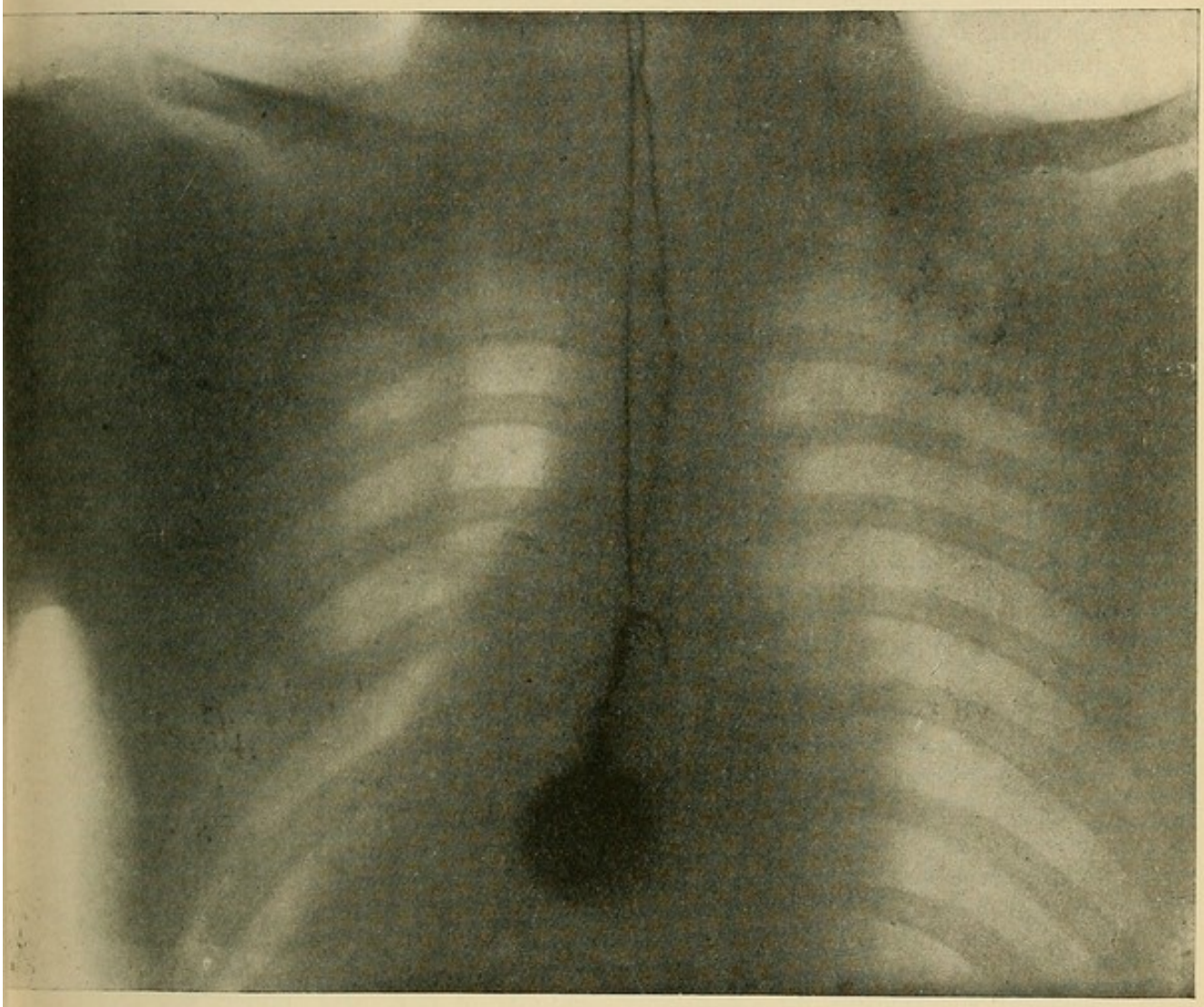


FIG. 80.—WATCH AND CHAIN IN ŒSOPHAGUS, SWALLOWED BY 'OSTRICH MAN' (*American X-Ray Journal*, July, 1898).

Foreign bodies can be readily detected in the stomachs of children, and sometimes in those of adults. Thus, Dr. Scott, of Kansas, has published the following interesting case, accompanied with a Röntgen photograph :

'Radiograph of abdomen of ostrich-man, Mr. G. W. Whallen, taken by Dr. E. Von Quast. The dark mass on the left side of the picture contained 116 different pieces of metal and a handful of glass. Patient operated upon, June 8, 1897, at German Hospital. Occupation, showman ; 26 years old.

Median gastrotomy. The following foreign bodies removed: 3 ounces glass, two pocket-knives (one a Varlow 4½ inches long, the other a four-blade), five knife-blades, one barb-wire staple, three screws, one horse-shoe nail, sixteen tacks, forty-one wire nails, forty-one twelve-penny nails. On account of the weight of the above articles the stomach was lower down than normal. The outline of the article does not show, as they were all rolled up in a round mass. Patient emaciated from want of food, as he could not eat anything for about a week before operation. Foreign bodies had been in stomach for two or three weeks. After operation the stomach was closed by interrupted and Lembert sutures. Death in forty-eight hours from enteritis and exhaustion. There had been hæmorrhage from the bowels. The post-mortem showed absolute union of wound in stomach; no leakage; wound healed in part.'*

In the same article Dr. Scott shows the radiogram of a swallowed watch in the lower end of the œsophagus of the ostrich-man. Immediately after the photograph was taken the patient removed the watch by means of the attached chain. Both watch and chain stand out in dark shadow upon the less dense record of the heart and spine. In the lower part of the course the chain bends slightly towards the left, thus following the direction of the œsophagus. The subject of this experiment was in the habit of swallowing wadded cartridges, tacks, money, screws, and other solid articles at public performances. He stated that as a rule he passed metallic bodies in twenty-four hours. A failure in that respect appears to have led to an accumulation and fatal result.

Dr. W. S. Halstead,† Professor of Surgery, Johns Hopkins University, has published a radiogram of the stomach of a juggler, aged twenty-one, from whom he removed 208 foreign bodies and 74 grammes of glass by the operation of gastrotomy on March 14, 1900. Recovery was rapid and complete. The list of articles removed included twenty pieces of small dog-chain, eight pieces of other chain, fifty-four wire nails, thirty-five ordinary nails, seven knife-blades, and numerous other things.

Professor Halstead does not mention the total weight of the articles removed, but he has appended an excellent epitome of the literature of foreign bodies removed successfully by gastrotomy. A girl of ten years, under Mr. Mayo Robson's care (see *Lancet*, 1894, p. 1028), furnished the record number.

This case should be compared with the one figured on p. 162 of the present volume. Dr. Halstead's radiogram shows an equally blurred outline of stomach contents, with no indications of the details of the contained mass of articles.

Abdomen.

J. H. Morgan‡ removed a piece of stay-busk from the stomach of a man; no *x*-ray record visible, because metal was perpendicular to the sensitive plate.

* *American X-Ray Journal*, July, 1898.

† *Johns Hopkins Hospital Reports*, vol. ix., 1900, p. 1054.

‡ *Lancet*, February 5, 1898.

N. Davies Colley* removed a packing-needle, 4 inches long, swallowed by a woman of thirty-six four months previously. She had obstinate constipation and painful swelling, 2 or 3 inches in diameter, above front half of left iliac crest. With the rays the needle was visible, lying in a nearly vertical position. On cutting through the muscles some fibrinous exudation was found upon the transversalis muscle. On the supposition that the needle had been pushed back into the bowel, the wound was then closed. A month later, the needle not having been passed per rectum, it was removed from the descending colon by operation. A good localizing radiogram had been previously taken, which showed that the needle lay vertically about half-way between the middle line and the outline of the flank. Its lower extremity was reckoned to be 2½ inches from the surface, and its upper extremity a little further back. A noteworthy point was the rapid absorption of adhesions in the interval between the two operations.

Dr. White has suggested† that in suitable cases the presence of a foreign body in the stomach could be demonstrated by moderately distending that organ with a harmless opaque fluid, like lime-water, and observing whether or not the body disappeared from view.

Linderman suggests the outlining of a dilated stomach by means of a soft stomach-tube armed with a flexible metal style. A relative landmark on the abdomen is obtained by fixing a small coin upon the umbilicus.

MM. G. Leven and G. Barret‡ have outlined the stomach in gastroptosis by bismuth subnitrate in cases of ptosis of this organ, in the diagnosis of which they believe it will, in time, supplant the older and more inconvenient method of inflation.

Removal of Foreign Bodies from Stomach.

Mr. Stephen Mayou§ has devised a means of removing foreign bodies of a metallic nature from the stomach by passing down an electromagnet, enclosed within a flexible celluloid tube. By the aid of the *x*-rays the course taken by the magnet and its relation to the foreign body can be clearly seen. In the case of a boy, aged two, who had swallowed a hair-pin, this was successfully removed by this method without any occasion for a surgical operation.

Foreign Bodies in the Eye.

The Röntgen ray exploration of the eyeball, partially surrounded as it is by a bony socket of varying thickness, was in the early days

* *Lancet*, January 13, 1900, p. 96.

† *Deut. Med. Woch.*, April, 1897.

‡ *Comptes Rend. de la Soc. de Biologie*, October 30, 1903, p. 1218.

§ *Lancet*, December 6, 1902, p. 1536.

of Röntgen work attended with insurmountable difficulty. Now, however, it may be readily performed by the use of a tube of good penetration and definition, and in some cases yields results of great value.

So early in the history of radiography as March, 1896, Professor Van Duyse communicated some interesting experiments to the Medical Society of Gand. He introduced a shot into the eye of a rabbit, and pushed it up behind the iris towards the centre of the lens. He then, with the aid of a local anæsthetic, produced an exophthalmos, and slipped under the protuding eyeball a small sensitive plate. The result, an extremely sharp shadow, is shown in Fig. 81.

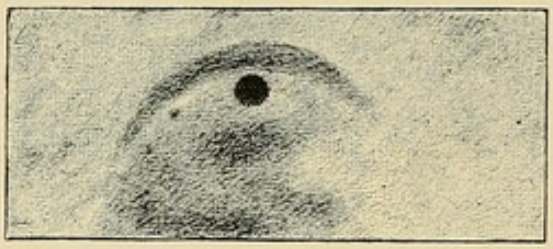


FIG. 81.—SHOT IN EYEBALL OF RABBIT.

An important point was that the foreign body could not be detected by the ophthalmoscope.

This second picture (Fig. 82) shows a pellet and a fragment of lead introduced into the equator of a human eye after removal from the body. Van Duyse concluded that: 'To obtain a shadow of metallic bodies lying in the anterior chamber, it will suffice to place, in the inner angle of the lids, a small sensitive plate or film of which one of the corners has been rounded, and to turn on the *x*-rays from the temporal side.'

For the use of both the above illustrations the writer is indebted to the courtesy of Dr. Van Duyse.

Many cases have been reported of the detection by the rays of foreign bodies in the living human eye.

Dr. Leukowitsch,* one of the early workers in this direction, obtained good results in sheep's eyes with two tubes, but found it better to use one tube and take two views.

For the living human eye he used small semicircular sensitized plates, as that shape allowed the largest possible area to be inserted at the inner angle of the eye opposite the lachrymal bone. By rolling the eye inwards or outwards, a large part of the globe could be brought within range of the rays. Rotation, however, rendered a fixing-point necessary. This he obtained by a glass indicator, bent twice at right angles, with a short straight ter-

* *Lancet*, August 15, 1896.

minal placed so as to point exactly to the antero-posterior axis of the centre of the cornea. In this way he obtained localizing radiograms of a foreign body (a sequin) placed on the conjunctiva of his own eyeball.

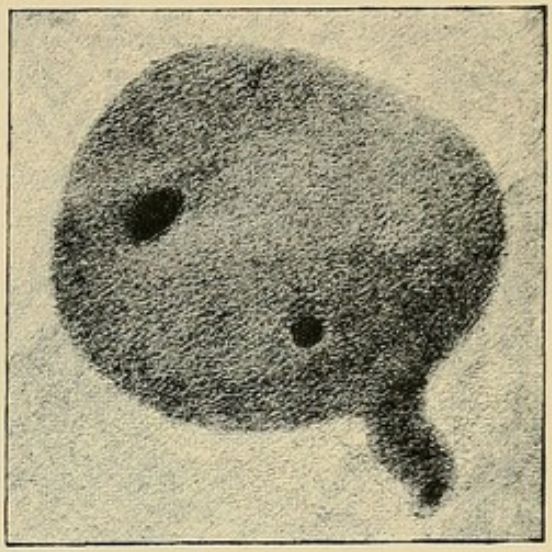


FIG. 82.—PELLET AND FRAGMENT OF LEAD IN HUMAN EYE.
Van Duyse.

In February, 1897, two cases of steel fragments in the vitreous humour were brought before the Ophthalmological Section of the College of Physicians, Philadelphia, by Drs. Oram Ring and Hansell. The latter gentleman mentioned another instance communicated to him verbally by Dr. de Schweinitz, who found a foreign body by the rays, and afterwards extracted it by the Hirschberg magnet. Dr. Hansell, in a communication to *The Journal*, Philadelphia, observed: 'Thus it will be seen that the bony walls of the orbit and the coats of the eye are permeable to the rays. By comparison of the shadow of the metal with that of the margin of the malar process of the superior maxillary bone, and the knowledge of the relation of the Crookes tube to the sensitive plate, the location of the foreign body can be closely estimated.'

Dr. Stern, of the Philadelphia Polyclinic, however, claims by an original method to have succeeded six times in demonstrating, by both fluoroscope and radiogram, foreign bodies in the eye, undiscoverable by other means. In each instance he reported subsequent removal by ophthalmologists. Before he detected the fragment in the case of Dr. de Schweinitz's patient, the eye had actually been cut down upon once, and the magnet applied three times with negative results.

Good records of small shot and fragments of wire introduced into orbits were obtained by Dahlefeld and Pohrt.* Their plan was to place the sensitive plate against the temple of the affected side, and to place the focus tube at a distance of 10 to 15 millimetres distant from the opposite temple. Then came the stage of exact localization, which in certain cases has rendered the *x*-rays invaluable to

* *Deut. Med. Woch.*, No. 18, 1897.

the ophthalmic surgeon. In America, Dr. Sweet* and Dr. Kibbe† appear to have led the way; and Dr. Sweet took Röntgen photographs in one or more of Dr. Hansell's cases where extraction followed. Dr. Leonard's method was published in April, 1898,‡ two months later than that of Mr. Davidson in England.§

An excellent account by Mr. Treacher Collins, of the Röntgen rays in relation to ophthalmology, was published in the *Practitioner* for August, 1898. He describes Dr. Sweet's method thus:

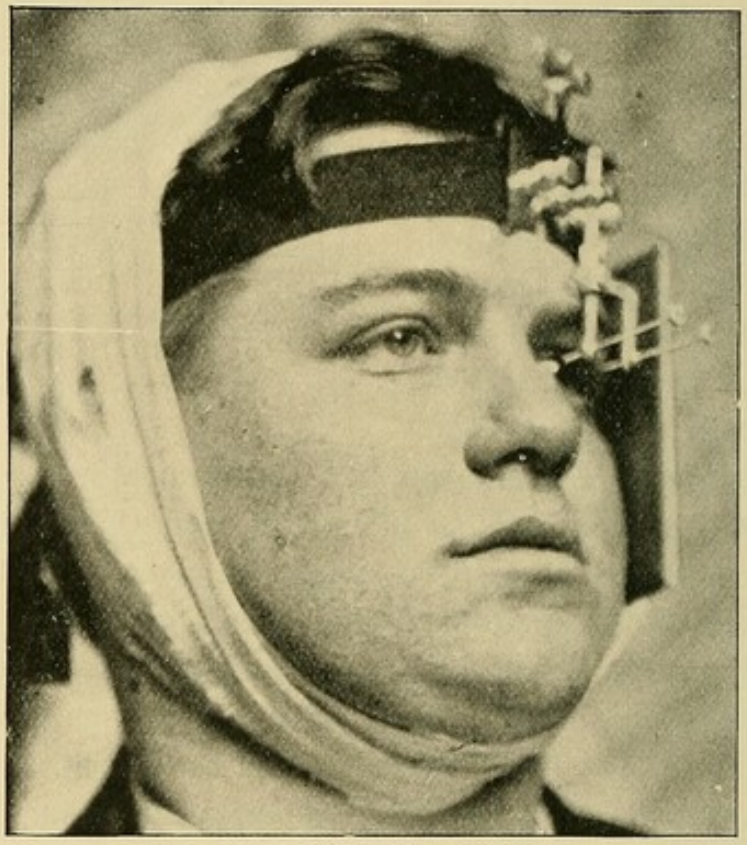


FIG. 83.—SWEET'S LOCALIZING APPARATUS.
From the *Practitioner*.

'Dr. Sweet fixes to the patient's head an "indicating apparatus," carrying two steel rods, each with a rounded ball at the end. These balls are placed at a known distance from the eyeball, one pointing to the centre of the cornea, the other to the external canthus, both parallel to the visual line and perpendicular to the plate.

'From the relation of the images of these balls of the indicator to that of the foreign body in the skiagraph he is able to work out,

* *Trans. Amer. Ophth. Soc.*, vol. viii., p. 88, 1897.
† *Archiv. of Ophth.*, vol. xxvi., p. 517, 1897.
‡ *Philadelphia Medical Journal*, February 5, 1898.
§ *British Medical Journal*, April 28, 1898.

on a horizontal and vertical diagrammatic section of the eyeball, the approximate position of the foreign body.

'In a patient of Dr. W. Thomson, of Philadelphia, who had received an injury to the eye eight months previously, Dr. Sweet predicted that the piece of steel would be found below the horizontal line of the eyeball, to the temporal side of the vertical one, and 20 millimetres from the cornea. The foreign body was subsequently removed by operation from the position indicated.'

Mr. Davidson applies the photographic plate, fixed in an angular rest, to the temple on the affected side of the patient, who sits upright. A loop of lead wire is fixed by sticking-plaster to the edge of the lower lid, opposite a known point of the eye; the point

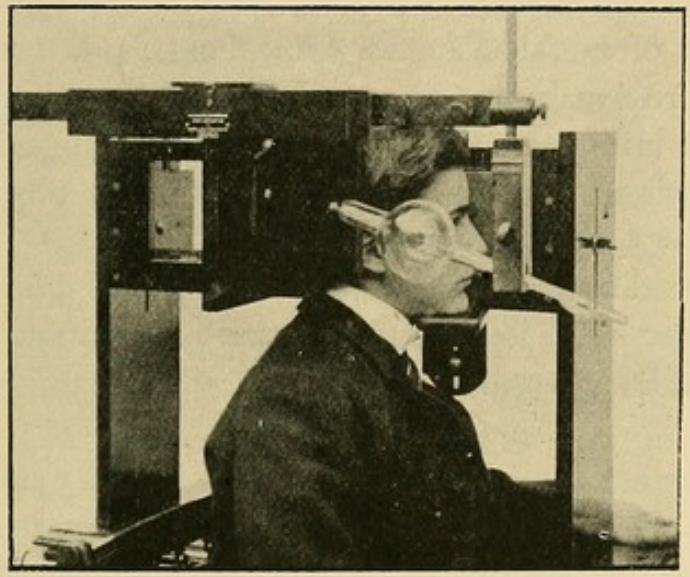


FIG. 84.—DAVIDSON'S EYE APPARATUS.

of this wire, projecting upwards, forms the landmark from which the position of the foreign body is calculated. The patient is directed to gaze steadily at a distant object in an axis parallel with the plate—that is, straight in front—and two exposures are made on the same plate with the tube in different positions on the sliding bar. Localization is made from the resulting photographic records in the manner already described, and has now been successfully applied by many ophthalmic surgeons.

Mr. T. Collins, at a meeting of the Ophthalmological Society on January 27, 1898, described a series of cases in which the above method had been used. In none of them could the presence of a foreign body have been determined from the clinical appearances.

In two of the cases the chip of steel was subsequently withdrawn by the introduction of an electromagnet in the direction in which it had been ascertained to lie. The size of one of these bits of steel was practically the same as had been estimated by Mr. Davidson previous to its removal. In another case, the eye being quiet, and two and a half months having elapsed since the injury, operative procedure was not thought justifiable. In a fourth case the eyeball was removed, and dissection showed the foreign body to lie in the position and be of the exact size predicted.

In taking these objects, often every minute, the tube must emit the rays from a small point on the anti-kathode, and the exposure must be short—say a minute to a minute and a half. The method may be illustrated from the following reports of actual cases where extraction was successful:

1. 'A chip of metal situated 3 millimetres external to a piece of lead wire previously fixed to the lower lid, 7 millimetres upwards from it, and 4 millimetres backwards. On working this out, it led to the conclusion that the foreign body was in the lens, directly behind the discoloured spot in the iris.'

2. 'Diagnosed the presence of a spicule of metal 5 millimetres in length, and located its lower end as situated 5 millimetres inwards, and 4 millimetres upwards, from a lead-wire pointer placed on the lower lid.'

3. 'He was able to diagnose the presence of an exceedingly small chip of metal (less than 1 millimetre in diameter) in the eye. He further located it 5 millimetres above, and 1 millimetre to the nasal side of, a pointer placed opposite a known point on the lower lid, and at a depth of 5 millimetres from the surface of the cornea. These measurements, worked out on the schematic eye, showed the foreign body to be situated in the lens, opposite about the centre of the outer half of the cornea.'*

The advantages of the method in ophthalmic surgery have been excellently summed up by Dr. Collins as follows:

1. They enable us in doubtful cases to determine the presence or absence of a metallic foreign body in the eye. With a good apparatus properly used, a piece of metal less than a millimetre in diameter can be detected in a skiagram.

2. The exact position in the eye of a foreign body can be located by the method, which allows of the procedure which will most

* *British Medical Journal*, August 20, 1898.

facilitate its removal to be deliberately planned, so that a minimum disturbance of the tissues of the eye is brought about.

3. The same method allows of the exact size of an unseen foreign body being ascertained, and of the size of the incision necessary for its removal being determined.

4. This method enables us to say whether or not a foreign body which has entered the eye has passed through it into the orbital tissues or remained in the eye, a point sometimes left in considerable doubt as the result of clinical examination. For example, it is by no means uncommon for a foreign body entering the front part of the eye to pass through the vitreous, strike the retina, and rebound into the anterior and lower part of the vitreous. In such a case, if the lens is not wounded, the foreign body may be invisible ophthalmoscopically, and the mark left where it struck the retina be taken for the aperture of exit of the foreign body.

5. The unsuspected presence or the absence of more than one foreign body may be demonstrated. In a case of Mr. Wray's several foreign bodies were shown scattered about in the orbital tissues, the eyeball having escaped injury.

In March, 1897, Benedikt* showed a radiogram of a man who had been injured in the right temporal bone several years previously. Since then his vision had gradually declined, together with the occurrence of retinal detachment. The onset of pain led to a radiographic exploration, which revealed a sharp body penetrating the orbit from the neighbourhood of the zygoma.

The humours of the eye appear to be somewhat resistant to the rays, and the crystalline lens markedly so, while the retina is insensitive to their vibrations.

The Röntgen Rays in Ophthalmic Surgery.

Mr. M. S. Mayou† has employed the rays with success in the treatment of trachoma, the patient being exposed for two minutes at a time, at a distance of 9 inches, on four to six successive days at first, and less frequently as the granules disappear. The advantages claimed by this method are: (1) less deformity of the lid after treatment; (2) it is practically painless; and (3) pannus disappears more completely.

Mr. Sidney Stephenson‡ and the author have also treated cases of

* *Medical Press and Circular*, April 7, 1897, p. 359.

† *Trans. Ophth. Soc.*, vol. xxii., p. 95, and vol. xxiii., p. 11.

‡ *Medical Press and Circular*, February 18, 1903, p. 155.

granular lids in this manner successfully. The present writer found at the same time that trachoma could be cured by the application of a 'high frequency' electrical current.

Mr. E. Treacher Collins* has reported considerable improvement in this affection after exposure to the *x*-rays in the children of the Metropolitan Asylums Board Ophthalmic Schools at White Oak, Swanley.

Tuberculosis of the Conjunctiva.

Mr. Sidney Stephenson† has reported the successful treatment of a case of tuberculosis of the conjunctiva in a child aged four years by means of the *x*-rays.

Calculi in Various Positions.

The detection of stones in internal organs, closely connected with the subject of foreign bodies, is likely to become an important branch of radiography. Under present methods, however, results are still more or less uncertain in the case of renal and biliary concretions, and not altogether certain in those of the urinary bladder. For all that, stone has been shown by the radiogram to exist in the gall pouch, in the urinary bladder, and in the kidney of the adult living human subject.

So far as the opacities of the various calculi are concerned, both Neisser and Petersen have demonstrated that while cholesterine concretions are almost transparent, those of phosphates and urates are opaque to the rays. From these premises they concluded that it would be impossible to detect gall-stones by the rays, yet stone in the bladder and the kidney might be thus demonstrated.

Biliary Calculi.

MM. Mauclaire and Infroit‡ have succeeded in obtaining a good radiogram of gall-stones lying in the fundus of the gall-bladder in a female patient in whom the clinical diagnosis was thereby confirmed prior to operation. Hitherto the translucency of biliary calculi, together with the respiratory movements of the gall-bladder, have rendered their detection a matter of great difficulty. The radiographic technique is all-important. In former attempts the patient was placed in the prone position, so that the gall-bladder might be as

* *Annual Report Metropolitan Asylums Board*, 1903, p. 83.

† *British Medical Journal*, June 6, 1903, p. 1813.

‡ *Comptes Rend. de l'Acad. des Sciences*, Paris, September 21, 1903, p. 482.

near to the plate as possible, but this proved too painful a process. In the present case the patient lay upon her back, the abdomen being compressed by the application of a firm linen binder. A tube of small penetrating power was employed, and a ten minutes' exposure was given. After the operation of cholecystotomy had been performed, radiograms were taken of the dried calculi. It was found that the degree of translucency to the rays was in inverse ratio to the amount of mineral matter which they contained. The number of calculi did not affect the clearness of the resulting skiagraph. In the same gall-bladder stones of different chemical composition could be detected. The authors are continuing their researches to see whether it is practicable to detect the presence of gall-stones in the common bile-duct.

Urinary Calculi.

Messrs. Laurie and Leon, in a paper in the *Lancet*, January 16, 1897, published results of experiments showing that calculi of oxalate or of phosphate of lime were more opaque than bone, uric acid of almost the same opacity, and gall-stones very slightly more opaque than flesh. They thus substantially confirmed previous results arrived at by Mr. Henry Morris. Experiments upon gall-stones have been reported by Messrs. Neisser, Goodspeed and Cattell,* and many others.

In France Messrs. Chapuis and Chauvel at an early date studied kidney calculus in relation to the rays. They concluded that stones composed of uric acid, urates, and phosphates were little less opaque than bone. Those composed of many layers and of unequal opacity proved by analysis to consist of uric acid nuclei covered with layers containing phosphates. They found the kidney substance less penetrable than muscular tissue, so that the kidney appeared as a light patch on the negative (dark in the print).

In a radiogram of a removed kidney a stone shows as a dark body. Many excellent examples of this sort have been published from time to time. †

To Dr. Macintyre, of Glasgow, belongs the distinction of having obtained the first focus-tube record of a renal calculus *in situ*. ‡ It appears that he had failed to demonstrate any concretion in half a

* *Medical News*, February 15, 1896.

† See plate in Morton's '*X*-Ray,' New York, 1896.

‡ *Lancet* for July 11, 1896.

dozen cases where stone in the kidney was suspected. Undeterred by these negative results, however, he tried the Röntgen rays upon another patient who had been previously operated upon for the malady in question. Thereupon, with a 6-inch spark and twelve minutes' exposure, he was rewarded by a clear record on a Paget XXXXX sensitive plate. 'In this instance,' to use his own words, 'at the correct situation, a picture of an obliquely-placed elongated deposit was obtained.' From his reading of the result Dr. Macintyre inferred the presence in the kidney of a stone, but not a well-formed one. The correctness of his inference was subsequently proved by Mr. Adams, of Glasgow, who, on operating, found at the bottom of an old cicatrix an ill-defined mass, which he removed with a spoon.

Dr. James Swain, of Bristol, made some important observations on the subject. He exposed on a single plate various kinds of calculi of nearly uniform thickness to the rays for periods of one, two, four, eight, and sixteen minutes. He found the general law laid down by Röntgen, namely, that the denser the object the deeper the shadow, did not apply exactly to these experiments. Arranged in the order of the highest specific gravity, the greatest permeability to the rays, and the greatest density of the shadow, the results are :

Specific Gravity.	*Permeability.*	*Density of Shadow.*
1. Oxalate of lime.	Biliary.	Oxalate of lime.
2. Uric acid.	Uric acid.	Phosphatic.
3. Phosphatic.	Phosphatic.	Uric acid.
4. Biliary.	Oxalate of lime.	Biliary.

Dr. Swain exposed each of the above kinds of calculi, together with a piece of human rib and a portion of kidney. With each increase of exposure the shadows became fainter, until at length, after an exposure of sixteen minutes, only the oxalic acid and phosphatic calculi, with the merest trace of rib, were to be seen. The important deductions are that a short exposure may give a better result than a long one, and that an oxalate of lime calculus will be much easier to detect than one of phosphates or of uric acid. If the exposure be too long, some of the less dense calculi will disappear altogether.

The uric acid calculus in an eight minutes' exposure gave a less dense shadow than that of rib, and much less, again, than that

of a piece of rib covered with kidney. The extreme difficulty of diagnosing uric acid calculi by the Röntgen method is therefore obvious.

Objects that could not be printed from the photographic plate were, nevertheless, at times visible to the eye. Hence it is always desirable to study the negative to avoid missing shadows not evident in the print. This observation was applied by Dr. Swain to a case where a patient was suspected to have a stone in the kidney. The *x*-ray negative showed a distinct shadow in the region of the left kidney, but no satisfactory print was obtainable. This result was taken as confirmatory, and a subsequent successful operation removed a stone half as large as a walnut.

Alsberg* reported a case where the signs and symptoms of renal calculus left the diagnosis doubtful. The rays, however, showed a sharply-defined shadow, 3·5 centimetres long, 2·25 centimetres wide, between 3 and 4 inches above the crest of the ilium. The presence of a smaller group of stones was also disclosed. A large stone weighing over 2 drachms was subsequently taken from the pelvis of the kidney, while from a calyx at the lower end of that organ a collection of seven small stones was removed. The calculi were of oxalate of lime. In this instance not only was a doubtful diagnosis cleared up, but important indications were also afforded to the operator.

Mr. Edward W. H. Shenton,† radiographer to Guy's Hospital, has summarized the results of 200 *x*-ray examinations for suspected renal calculus. Positive evidence was obtained in 39 instances, while in 8 cases the surgeon found calculi not shown by the rays. The remaining 153 cases were regarded as doubtful, as they had not been operated upon, but in most instances the negative evidence of the rays was confirmed by the after-history.

Renal Calculus.

This subject is discussed by Dr. C. L. Leonard‡ in an article dealing with fifty-nine suspected cases, in twelve of which a positive result was obtained. One negative result proved misleading, as a calculus was afterwards found. The error in that instance was due to the use of too small a plate.

* *Münchener Med. Wochenschrift*, December 20, 1898.
† *Guy's Hospital Reports*, vol. lvi., p. 98, 1902.
‡ *Annals of Surgery*, 1900, p. 162.

Jonathan Hutchinson, junior, F.R.C.S.,* read an excellent paper before the Section of Surgery at the Cheltenham meeting of the British Medical Association.

'The skilled use of the Röntgen rays,' he remarks, 'will now rarely fail to demonstrate both the exact position and the size of any renal stone. The early and positive recognition of the latter not only secures resort to operation before the calculus has led to secondary degeneration of the kidney, but in certain doubtful cases the proof afforded by the rays that no stone exists will save the patient from an unnecessary, and possibly dangerous, exploratory operation. In no department of surgery has the discovery been of more practical use than in that of the kidney. It is especially with regard to the kind and severity of the operation required that the *x*-rays are so valuable. They will, for example, in a given case tell the surgeon that there is a single stone 1½ inches long placed transversely 3 inches from the first lumbar spine and the same distance from the iliac crest. The operation becomes then merely the extraction of a somewhat deeply-placed foreign body. There is no object for an incision longer than is required to give free access, and still less for disturbing the relations of the kidney or forcibly dragging it into the light of day, or for prodding it in all directions with needles.'

The accompanying radiogram of a renal calculus is reproduced by courtesy of the author (Fig. 85).

Mr. Hutchinson's conclusions are:

1. The *x*-rays (except, perhaps, in stout subjects, or in the case of very small stones) enable an exact diagnosis as to size, position, and number of renal calculi to be made.

2. They enable the surgeon in performing the operation of nephrolithotomy to do so with the least possible injury to the kidney, and to dispense with bringing that organ to the surface of the wound.

3. Limited incisions made directly over the calculi through the renal pelvis are to be preferred when practicable. Such wounds of the pelvis heal well.

4. Before the operation it is most important to get the urine in a healthy condition.

5. Renal calculi, however small, should be operated on as soon as they are diagnosed. Their danger to the kidney structure and to the patient's life bears no relation to their size.

* *British Medical Journal*, October 19, 1901, p. 1131.

With regard to renal calculi, it may be remarked that there is no method yet devised of securing a radiographic record in the case of very fat patients. Hence, in giving details of cases, it is always important to note the girth of the person as well as the length of the exposure. Probably no renal calculus could be taken

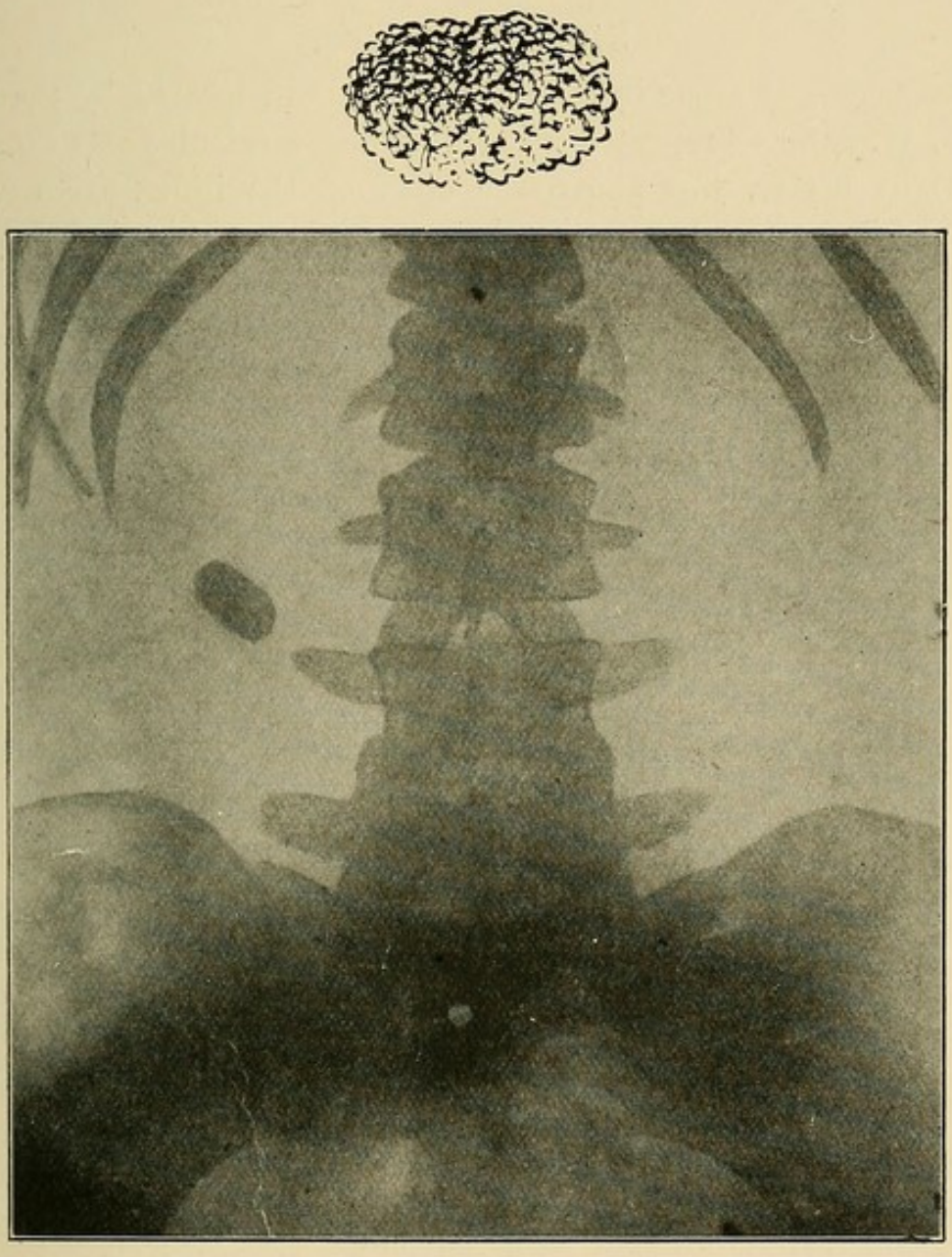


FIG. 85.—STONE IN KIDNEY. THE STONE IS SHOWN ABOVE (FULL SIZE); PLATE REDUCED.

in fifteen seconds, except in the case of a very thin subject. With modern apparatus it takes several minutes to get through the abdomen of a stoutly-built man—say 40 inches round the chest. In a patient who measured 45 inches round the abdomen, the present writer was able to secure a record of ribs and spine. The

likelihood of finding a small calculus is greatly increased by the use of a good form of compression-diaphragm, whereby definition is improved owing to the cutting of secondary or *s*-rays, while at the same time the thickness of tissue to be penetrated by the rays is reduced.

Stone in Ureter.

Many cases of stone in the ureter have been located by the rays. Dr. J. W. Elliott* reported a case in which a calculus was shown in the right ureter, just above the crest of the ilium, from which position it was readily removed by operation. He alluded to six other cases mentioned by Leonard.

A good case has been published by W. W. Keen, M.D.,† of a calculus located in the ureter by the Röntgen rays, and afterwards removed by operation. The patient was a boy of ten years, who had a history of an attack of hæmaturia at two years of age. From five to ten there were recurrent seizures of pain in region of left kidney, extending to scrotum and penis. The calculus, which was rough and dark, consisted of calcium phosphate, and lay in a pouch partly intra-ureteral and partly formed between the ureter and the rectum.

The stereoscopic method is of especial value in locating stones in this position. Mr. Mackenzie Davidson has shown some striking results obtained in this way, notably one in which a kink of the ureter was loaded with small calculi or calculous material, and another which showed a dilated ureter. Except by the stereoscope, it is difficult or impossible to locate the exact position of ureteral stones, a consideration worthy of the careful attention of every operating surgeon.

Mr. Hurry Fenwick at one time applied a specially-constructed fluoroscope to detect the presence of small, deeply-placed stones in the kidney. As a preliminary step the kidney was brought out on the loin, and the room darkened for the screen examination.‡

The original of Fig. 86 was kindly furnished the writer by Mr. Davidson. It shows very clearly a uric acid calculus in the urinary bladder of a living male, twenty-eight years of age. The size of the stone was estimated at 3 to 4 centimetres, and its actual

* *Boston Medical and Surgical Journal*, May 16, 1901, p. 474.
† *Journal of the American Medical Association*, August 31, 1901, p. 567.
‡ *British Medical Journal*, October 16, 1897.

diameter when removed by Professor Ogston turned out to be 3·2 centimetres. The apparatus used was a 10-inch spark coil of

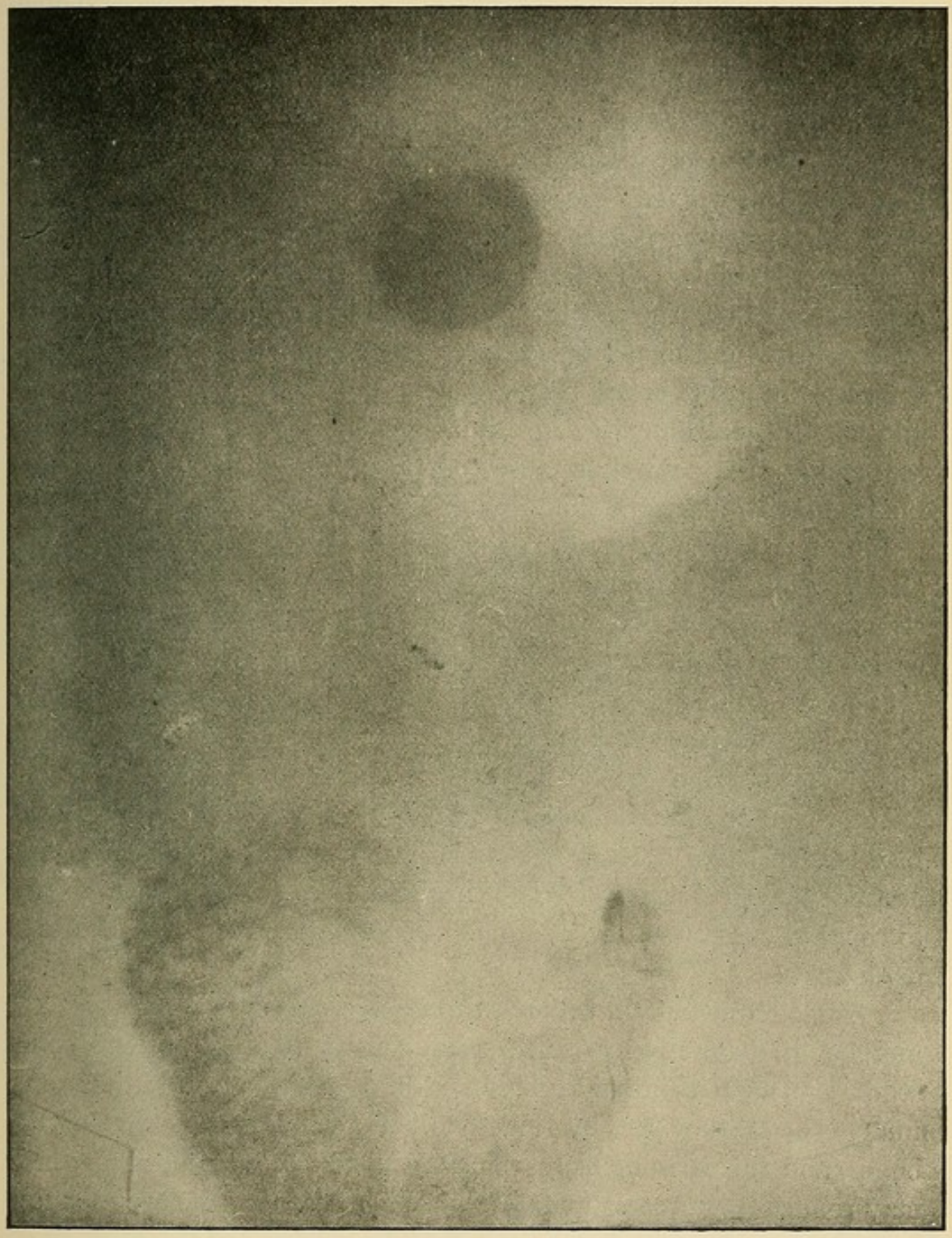


FIG. 86.—STONE IN BLADDER.
M. Davidson, M.B.

Apps. During exposure the patient lay on his belly, and a remarkable print of the scrotum appears on the plate. This phenomenon is attributed by the operator to the moisture of the parts having

penetrated the two folds of sateen cloth which covered the plate and moistened the gelantine film so that the cloth slightly adhered to and impressed the film. To obviate similar occurrences, which he had noted more than once, he has since used waterproof paraffined paper for colouring the plates. It is open to some question if this interesting phenomenon is quite so easily explained, for warmth, pressure, and electrical action, to say nothing of moisture, might be one or all involved.

In the foregoing case the patient, as already stated, was on his belly, so that the stone, which lay loose in the bladder, was brought near the plate. The rays were then passed obliquely through the lower outlet of the pelvis, so as to fall obliquely on the recording surface, the tube being placed below the buttocks. In children, and also in suitable cases in adults, a good result can be obtained by placing the focus-tube close to the sacrum, with the patient on his face, and taking the photograph through the pelvis.

It seems tolerably certain, then, in the light of what has been already done in this important branch of surgery, that the demonstration of all internal calculi of any size in the adult will sooner or later be within the power of the Röntgen ray operator. At present it is difficult or impossible to obtain any satisfactory results in the case of stout persons, and the operator who undertakes such cases must be prepared for disappointment.

Improved apparatus has enabled operators to detect stone in the bladder, kidney, and ureter with much greater precision and certainty than formerly. The position of the rays with regard to renal calculus was fairly summed up in 1901 by Mr. P. J. Freyer,* as follows:

'The circumstances which militate against the success of this method of diagnosis are: The stone being small, the patient being stout, the movements of the kidney during respiration blurring the image, the shadow cast by the stone being concealed by that of the bones, and the calculus being phosphatic, any one or more of which may render this process nugatory. When a distinct isolated shadow resembling a stone is shown, you may be pretty certain that there is one present. But negative evidence as to the presence of stone by the Röntgen rays should not deter you from exploring the kidney by operation when the symptoms of stone are well marked.'

* *British Medical Journal*, May 25, 1901, p. 1258.

II. BONES.

(*a*) GENERAL REMARKS.

The following experiment was devised by the author with a view of ascertaining to what particular element of bone the Röntgen ray shadow of bone was due. Three small bones were taken from just above the hoof of a sheep; the first was left in its natural condition, the second decalcified by soaking for several days in dilute hydrochloric acid, and the third calcined in a furnace. The three bones thus prepared were placed side by side on a sensitive plate, and subjected to the rays, with the result reproduced in

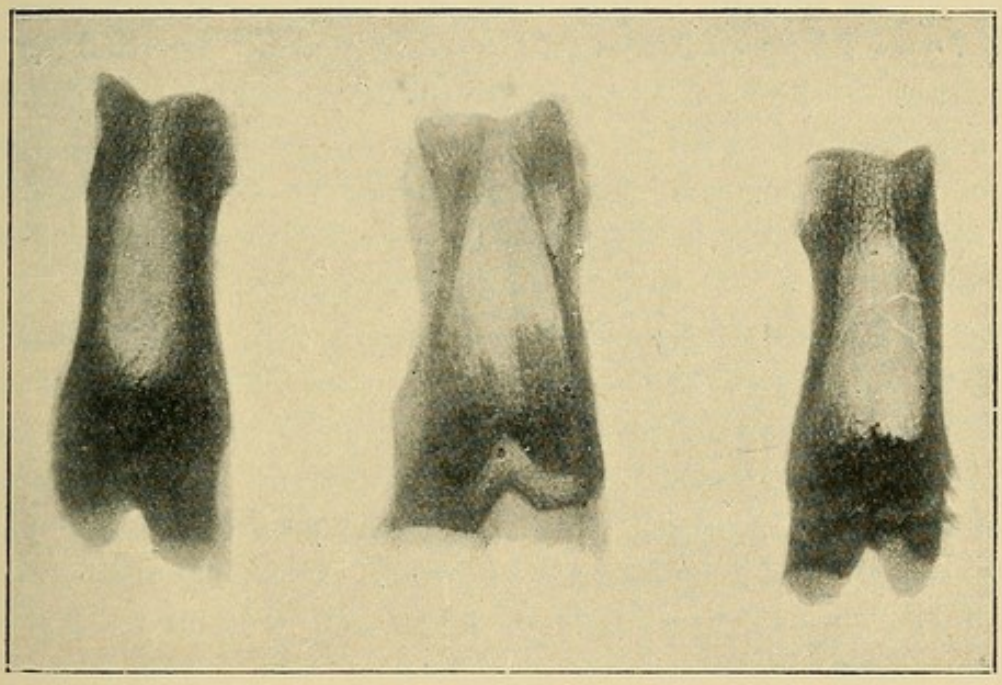


FIG. 87.—THREE SMALL BONES FROM FOOT OF SHEEP: ON LEFT, NORMAL; IN CENTRE, DECALCIFIED; ON RIGHT, CALCINED (AND CRACKED BY THE HEAT).

Fig. 87. The normal bone on the left affords a standard for relative comparison; the centre or decalcified one casts a much fainter shadow; and the calcined one on the right yields a photographic record as dark as the normal bone, but sharper and clearer in detail. It should be noted that the process of decalcification was not completely carried out, so that some of the shadow in the centre bone, especially in its lower portion, is doubtless due to lime salts

that have not been entirely removed by the acid. This simple experiment seems to show that the main part of the shadow thrown by bone is due to its contained lime salts.

The opacity of bone to the Röntgen rays is much greater than that of the neighbouring soft tissues—a fact doubtless due to the earthy matters which form three-fourths of osseous structure. This quality enables us, by means of the 'new photography,' to obtain a sharply-defined shadow of most of the bones of the human body. Where the bones do not overlap, and the soft parts around are comparatively thin, as in the hand, a record can be quickly obtained upon either the screen or the sensitive plate. But in the pelvis, where the parts are thick and the bones more or less overlapping, the resulting photograph is obscured. In the case of the head, each half of the skull is more or less recorded on the plate, so that a blurred picture of double shadows result. For all that, the surface next the plate is always the more sharply recorded, so that indications of the utmost value are often obtainable from Röntgen ray examinations both of skull and of pelvis. In both instances the size of the bones has much to do with results; a thin skull or pelvis is obviously far easier to penetrate than a thick one.

Bones being relatively opaque to the rays, it follows that any break in continuity of body or of outline, and any abnormal position in relation to joints, will be readily detected by means of the Röntgen methods. As a matter of fact, not only are fractures and dislocations indicated in this way, but also many other pathological states, such as periostitis, exostosis, caries, and the formation of callus. The surgeon, indeed, when called upon to deal with injuries and diseases of bone, has been furnished with a new and accurate weapon of investigation. Instead of long and painful manipulations, often ending in nothing better than a suspended judgment, he will in many instances be able after an appeal to the rays to give offhand a definite diagnosis and prognosis. Such results, it should be noted, may be obtained by a skilful operator without causing the patient additional pain, and without taking off splints (if non-metallic), bandages, or dressings.

In order to read his results aright, the surgeon should make himself familiar with the radiographic appearances of bone, both in a healthy and in an abnormal state. A workman's hand, injured many years previously in a machine accident, is portrayed in

Fig. 88. The hand, it may perhaps be pointed out, is the right, and not the left, as might be at first imagined by anyone unfamiliar with the process. The reason is that the photograph is taken by transmitted and not by reflected light, so that we have on the sensitive plate the record of a shadow, and this is reversed in the process of printing. Owing to the non-recognition of this fact by the surgeon, the wrong hand is said to have been actually operated upon. Healthy bone appears as a dark shadow with a more or less well-defined outline, and where it is thinner and more spongy, as in the bosses projecting sideways from the distal ends of the metacarpals, and in the small sesamoid bone below the metacarpo-phalangeal joint of the thumb, the image is fainter. The thin bones and parts of bones are, in fact, overexposed. In taking a radiogram of a hand and forearm, an exposure that will bring out details of radius and ulna will more or less blot out the thin terminal finger-bones. The joints are indicated by clearly marked light intervals between the bones, where the rays have penetrated the intervening articular cartilages.

A point worthy of passing notice is that the sesamoid bones of the hand often show as well-defined spots, the size of small shot, through the distal portions of one or more of the metacarpal bones. In that position they have been mistaken at times for a pathological condition. The sesamoid over the metacarpo-phalangeal joint of the thumb is usually taken in profile, and, falling clear of the thumb-bones, presents a sharp picture. Dr. Clendinnen, of Melbourne, has published a Röntgen photograph of the mummied hand of a nobleman's wife, aged twenty-five years, entombed at Memphis 1500 B.C.* No less than five sesamoid bones are shown—one over each of the metacarpo-phalangeal joints of the index and little fingers, two at the metacarpo-phalangeal joint of the thumb, and one over the ungual phalanx of the thumb. The latter abnormality is to be found now and then in modern hands.

As to the abnormal hand (Fig. 88), the reader will do well to study it carefully in detail. The phalanges of the three remaining fingers are enlarged and dark, while the usual gaps between the end joints of the middle and ring digits have disappeared. The most likely reading of these recorded facts is that the fingers have been affected with chronic osteo-arthropathy, which has enlarged the bones and obscured or obliterated some of the joints.

* *Intercolonial Medical Journal of Australasia*, February 20, 1898, p. 106.

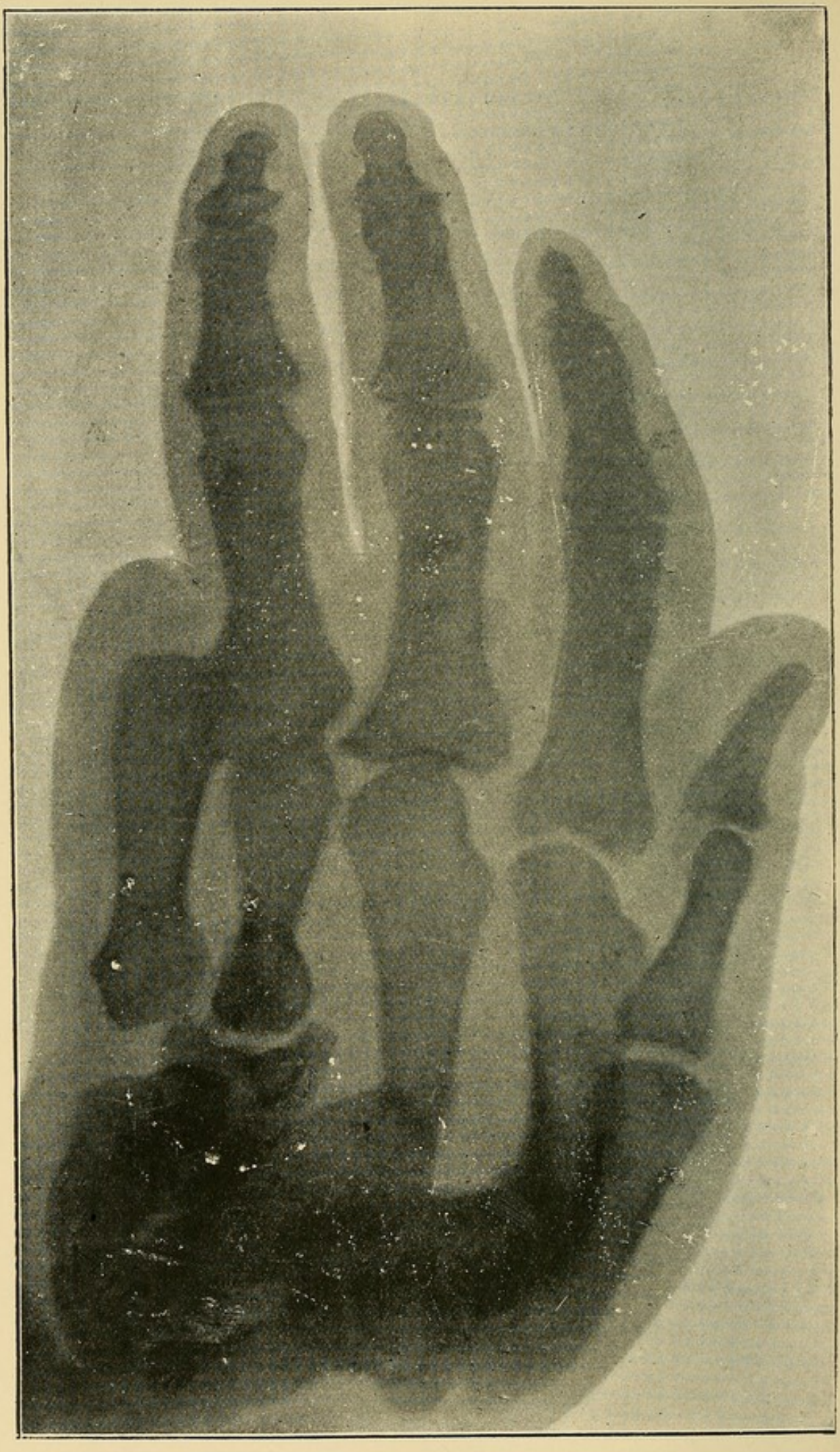


FIG. 88.—INJURED RIGHT HAND OF WORKMAN.
Mr. Greenhill (early work).

As regards pathological conditions, the following appear to be probable:

1. Old greenstick fracture (thumb metacarpal).
2. Malunited fracture (right angle, second metacarpal).
3. False joint (this may possibly be bony union; third metacarpal).
4. Impacted fracture (bony union, fourth metacarpal shaft).
5. New articulation (fourth metacarpal base).
6. Bony anchylosis (distal end of fifth metacarpal and first phalanx of fourth).
7. Fibrous and partially osseous anchylosis (base of fourth and fifth metacarpals).
8. Dislocation (multiple, carpus).
9. Compensatory curving of bones (twisted index-finger).
10. Bone hypertrophy (various bones).
11. Obliterated joint (terminal joints of second and third fingers).
12. Arrested development of distal epiphysis of first phalanx of middle and ring fingers.

One or two of the above explanations, especially in the absence of a careful examination of the hand itself, are perhaps open to an alternative reading.

(*b*) FRACTURES AND DISLOCATIONS.

EDITED BY LYNN THOMAS, C.B., F.R.C.S., OF CARDIFF.

Formation of Callus.

Manoury* of Chartres called attention to the formation of callus as watched by radiography. At the end of a dozen days there appears at the extremities of the fragments a light cloud that gradually becomes denser. If the fragments be accurately apposed, the callus forms at the level of the fracture a diffuse globular mass, which little by little becomes fusiform and compact. If there be slight overlapping, a cloudy deposit closes the medullary canal of each fragment, and makes a thick layer laterally at the level of contact. The time of formation of a definite callus is variable, and depends upon the thickness of the bone. In certain cases, especially

* Thirteenth International Congress of Medicine, Paris, (Section of Surgery), August 3, 1900.

oblique fractures of the tibia, the callus may remain for a long time invisible, almost up to the time of complete union.

The above evidently applies to the ossification of a subperiosteal callus, which, in the opinion of most English surgeons, would not be formed if absolute immobility were obtained.

Dr. C. L. Leonard,* of Philadelphia, writes :

'The advent of the Röntgen method into the diagnosis of fractures has created a higher standard by which the results obtained in the treatment of fractures must be judged. The practitioner can no longer be said to have employed all the means and knowledge to the best of his ability in the treatment of a fracture unless he has employed, or suggested to his patient the employment of, a skiagraph. In addition, if the skiagraph shows that perfect coaptation and fixation have not been secured, he must, at least, offer his patient the alternative of operative intervention, and employ it if it is desired.'

It is in these injuries, especially when obscure, that the Röntgen methods render unexpected and often brilliant results. For example, they are available when the surrounding parts are too swollen to admit of examination by ordinary methods, or when the manipulations of the surgeon cannot be borne by the patient without an anæsthetic.

At one time objection was made by some surgeons that the rays revealed nothing that could not be equally well learnt by other methods; but careful observations of *x*-ray photographs have demonstrated that not a few bone injuries occur in which it is impossible for any man, however skilful, to make an exact diagnosis —at one time, it may be, owing to swelling and tenderness of the parts, and at another to the obscurity of other evidence. Under such adverse circumstances precise evidence may forthwith be obtainable from the screen or radiogram. Moreover, the gain of this particular form of investigation does not end with recovery. In cases of an accident likely to come before a jury, the proof afforded by a photographic record of the bone condition may one day win a civil action, or vindicate the scientific reputation of the medical attendant—two points that will be referred to again under the heading of jurisprudence. Further, if the progress of a fracture be unsatisfactory, the surgeon can hardly be doing his duty either to himself or to his patient if he neglect the possible assistance to be gained

* *Physician and Surgeon*, March 22, 1900.

from a Röntgen photograph. Some medical men scout the idea of calling in the services of a professional radiographer to help them in arriving at a correct diagnosis. If that line of reasoning were sound, it would preclude them from sending specimens to a bacteriological laboratory to be tested for the presence of diphtheria bacillus, tubercle, typhoid, and other specific micro-organisms.

It is necessary to bear in mind that iodoform, bismuth, and some other metallic dressings are opaque to *x*-rays, as well as lead lotion and the various kinds of adhesive plaster that have a lead basis; but we have it on the testimony of the medical department of the Soudan Expedition that, although such effects injure radiographic results, they do not seriously impair the evidence thereby afforded.

Splints of felt, pasteboard, or wood are translucent, while those made of metal* are of course opaque. Plaster of Paris is dense, but a radiographic record can be obtained through such a splint by using a focus-tube of high penetration; the resulting photograph, however, is apt to be mottled and patchy, owing to the varying thickness of the plaster. A good substitute for plaster is the handy 'water-glass' or silicate of sodium splint, which is translucent to *x*-rays, and may be used conveniently where it is intended to take a Röntgen photograph during the progress of any particular case.

Nowhere is the necessity for comparative radiography more evident than in cases of obscure fracture. A slight peculiarity of the individual bone may be exaggerated into a pathological guise by the relative position of the tube, by the rays falling obliquely on the plate, or by an awkward attitude of the patient. In one case of alleged old-standing fracture of the external condyle of the humerus, the reading of the Röntgen photograph became a matter of pure conjecture until compared with another of the sound elbow taken under similar conditions.

A fracture may not be shown on the plate because the *x*-rays have not hit the gap in the bone in their straight passage from the anti-kathode to the sensitized plate. Then the break itself may be oblique, and thus interpose overlapping edges of bone between the source of the rays and the photographic surface. Mr. Lynn Thomas described an instructive experiment at a meeting of the Röntgen Society, May 1, 1899. He made parallel fret-saw cuts through the styloid processes of several ulnæ, and several more cuts into a

* Aluminium splints are practically translucent.

radius. The anti-kathode was fixed by means of a plumb-line directly over the second ulna, counting from the top downwards (see Fig. 89). The long axis of the tube ran parallel to the radius shown in the illustration. The latter bone was also incised with the fret-saw, and loops of wire twisted from the bottom of each saw-cut round the sound part of the shaft. The result is striking. The two upper cuts in the ulnæ show as unmistakable gaps. The next is less complete; while in the lowest one no change is visible in the bony substance. At the same time progressive distortion is shown in the shape of the ends of the ulnæ. The incisions in the radius become more and more V-shaped from above downwards, and the wire loops more and more oval.

'It will be observed that the fissure is more or less obscured by the shadow of the edges of the crack as we advance towards No 6. If we add, in fancy, the shadow cast by the soft tissues upon this radiograph, I feel quite sure that no unbiassed radiographer would accept the evidence as indicating a fracture. The different ulnæ have different density to *x* rays, owing to the different ages and sexes from which they were obtained.'

'In the radius we have a good example of the distortion a straight crack or fissure is liable to undergo by the position of the anti-kathode. The density of the adjacent edges of the compact bone of the radius—which, by the way, is nearly triangular in shape at the line of the fret-saws—is enough to allow a radiograph of the two surfaces of the fissure—*i.e.*, the one next the plate and the one next the Röntgen lamp—to appear distinctly. The result is a V-shaped light or transparent line with limbs of varying lengths. The angle of the V, as well as the limb of the V which is caused by the shadow of the crack furthest away from the plate, can be increased or diminished according to the operator's wish, or be converted into a straight line.'

'This experiment clearly shows the confusion and the distortion which arise from faulty positions of object, of tube, and of plate' (J. L. T.). It strengthens Mr. Lynn Thomas's plea for a standard point in the centre of the wrist in examining injuries of that region. At the same time it must be borne in mind that fractures which run either obliquely or spirally require much care and skill to be lucidly shown in a skiagraph, and occasionally it is necessary to take a series of *x*-ray photographs with the plate in front, behind, or at the side of the seat of fracture in order to get at the real pathological

condition. The use of the fluorescent screen is of consid erable value in determining the best situations for obtaining good skiagraphs. This fact can be verified by five minutes' careful examination of either an old Colles's fracture or the normal head and neck of the femur, by varying the position of the anti-kathode (in other words,

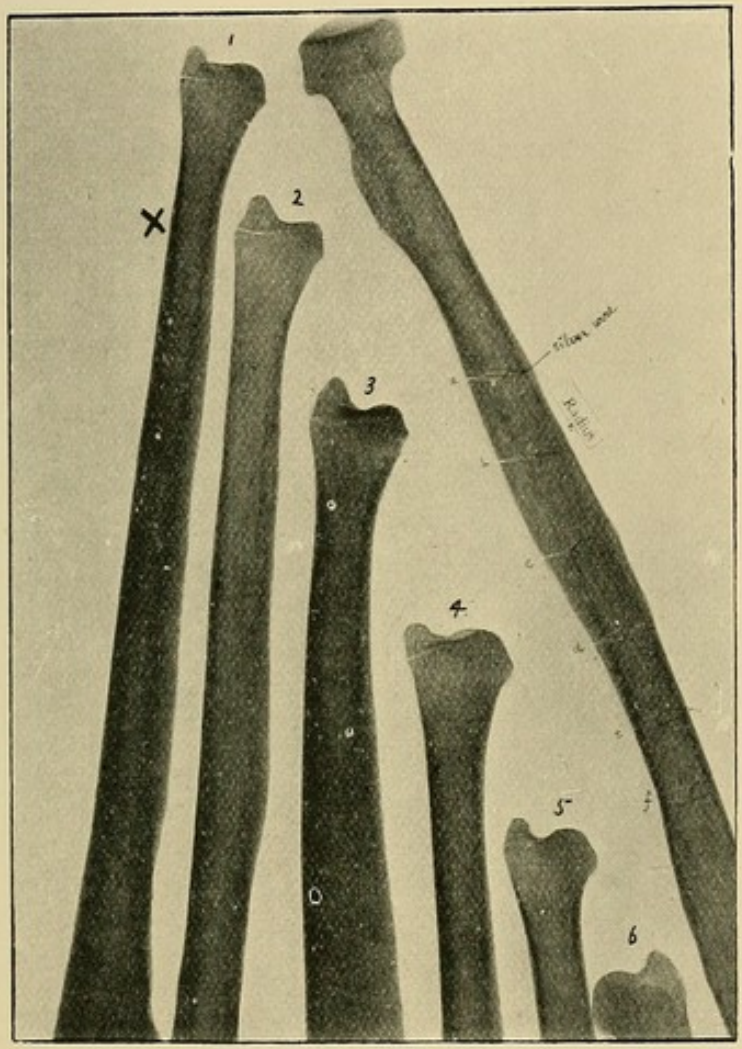


FIG. 89.—LYNN THOMAS'S DISTORTION EXPERIMENT.

(Six specimens of ulna with the bases of their styloid processes sawn through, but not detached, with a fret-saw. On the right is a radius with six fissures, made by the same fret-saw, through its ulnar margin.)

The anti-kathode of the focus tube was placed over the point X—*i.e.*, perpendicular to the base of the styloid process of No. 2 ulna.

by shifting the standard point of the vertical *x*-rays, which alone gives a true skiagraph of the normal relationship of parts) in every direction around the point under examination. The result is that the bones assume a variety of appearances of grotesqueness and unnaturalness owing to faulty perspective ; abnormal lengthenings or obscure shortenings appear, due solely to faulty appreciation of the

conditions essential to true skiagraphy. It cannot be too strongly insisted that the standard skiagram is the one in which 'the vertical rays from the standard point in the focus-tube fall through the area of the bone under observation upon the sensitized plate at right angles to their path; the slightest obliquity causes distortion.'

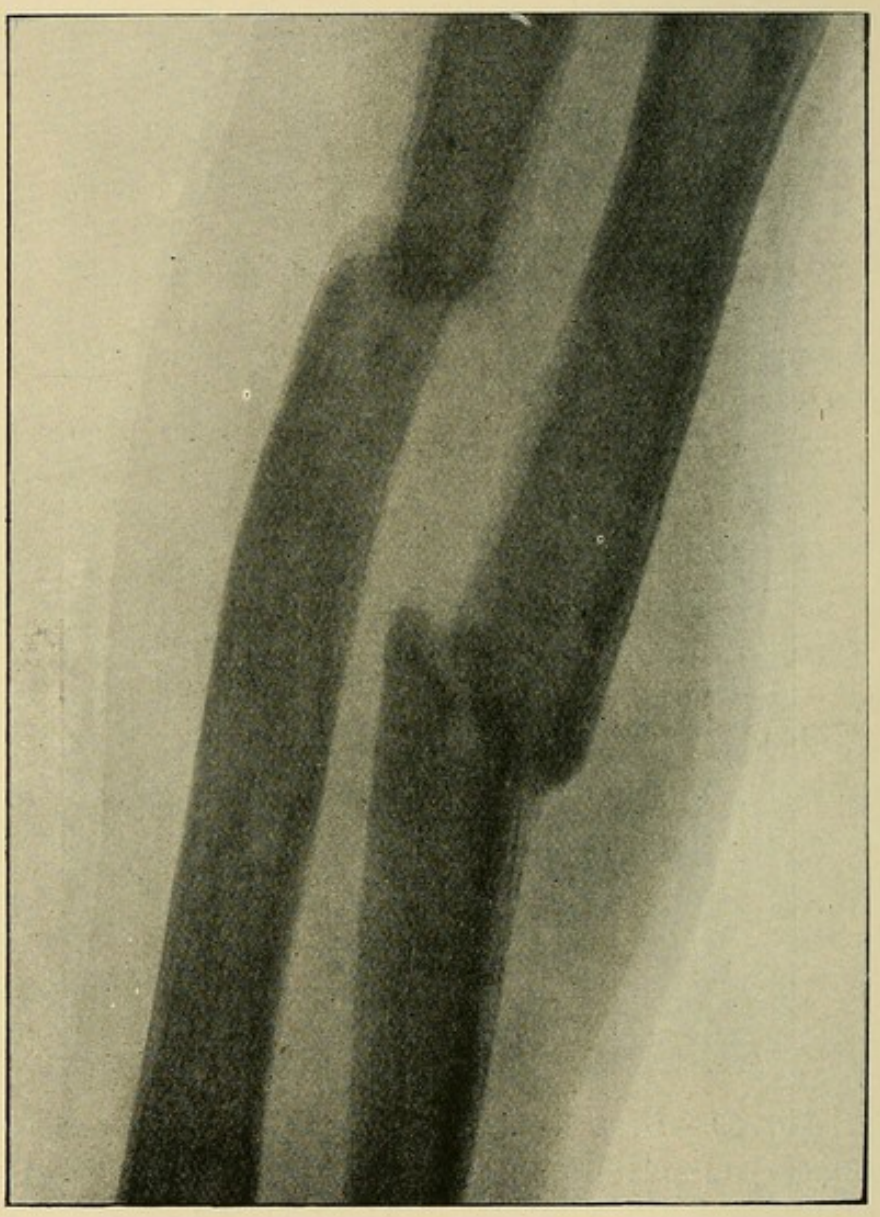


FIG. 90.—UNUNITED FRACTURE OF FOREARM.
Mr. Lane's case.

It seems likely that the Röntgen rays will help towards a truer conception of what really takes place in some particular injuries, such as Colles's fracture of the lower end of the radius (see Figs. 93, 94, etc.).

Of late a good deal has been heard of the practice of wiring recent fractures, such as those of the olecranon, lower end of fibula, patella, and of other bony parts where union is commonly delayed or vicious.

Under the conditions of modern surgery the plan appears to offer in many cases a good prospect of securing rapid bony union. It need hardly be added that the procedure consists in cutting down under aseptic precautions upon the broken ends, which are then drilled obliquely and brought together by stout silver wire. In this particular class of cases the surgeon will learn from the rays—(1)

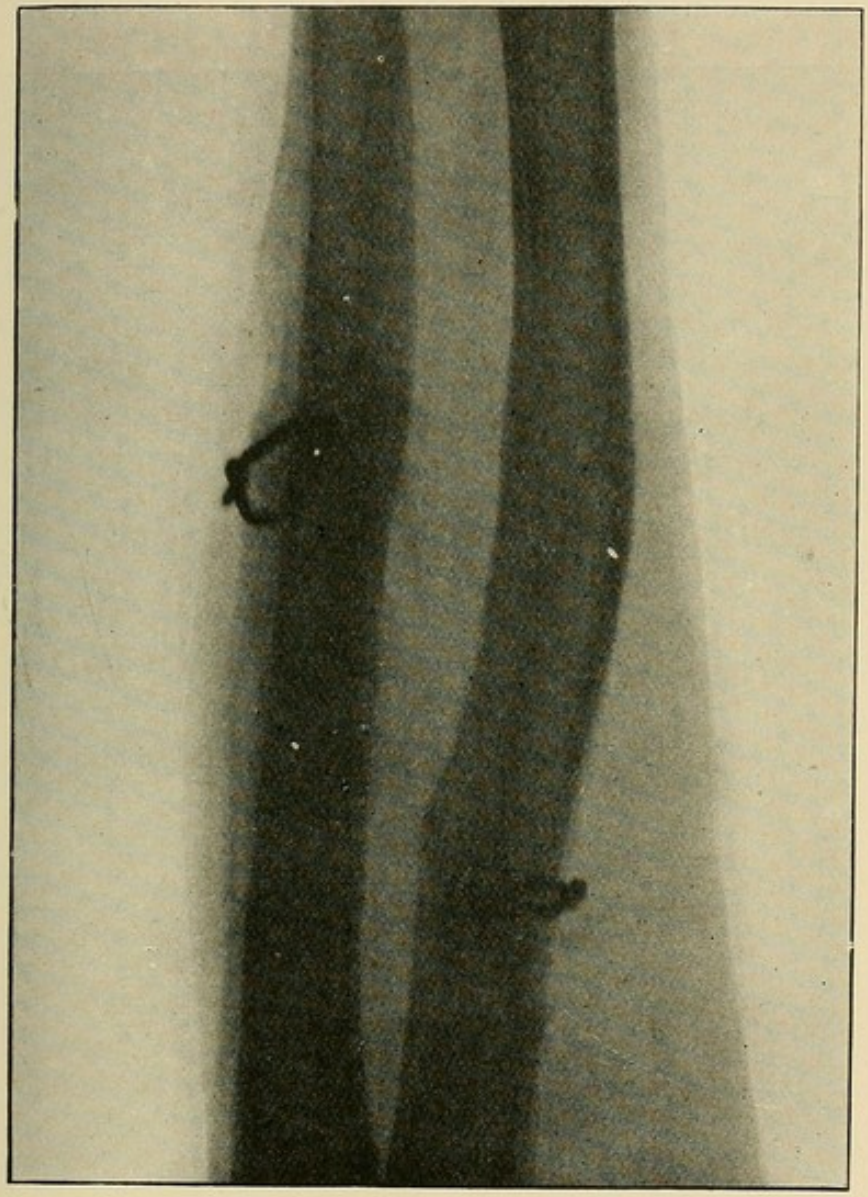


FIG. 91.—SAME FRACTURE AFTER WIRING.
Mr. Lane's case.

whether wiring is advisable; (2) whether proper apposition has been secured; (3) whether bony union has followed.

Wiring Fractures.

The accompanying radiograms (Figs. 90 and 91) show the bones of the forearm in a lad of sixteen, before and after the operation

of wiring. The case was under Mr. Arbuthnot Lane's care at Guy's Hospital.* The injury was of five weeks' standing. Both bones showed ununited fracture (Fig. 90), and the arm was flail-like.

Mr. Lane first freshened the broken ends of the ulna, and fastened them together with silver wire, and six weeks later treated the radius in a similar fashion. The result is shown in Fig. 91.

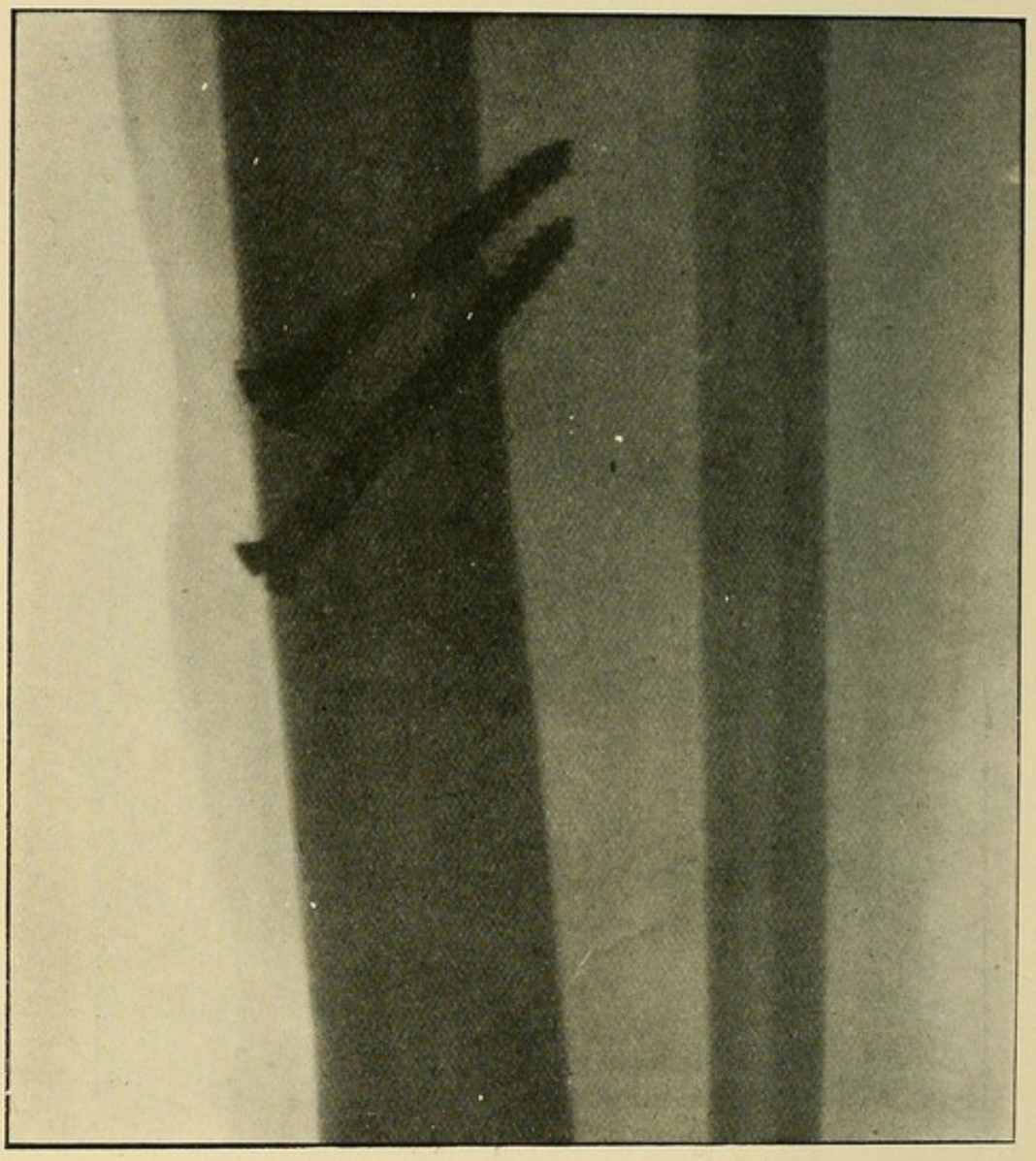


FIG. 92.—SCREWS IN TIBIA.
Lynn Thomas, F.R.C.S.

'The plan of "nailing" recent fractures of the condyles of the humerus, or of a loose fragment of bone, as advocated by some surgeons, would in many instances be hardly feasible without a clear knowledge of the condition of the broken bone, gained from a

* *Medical Press and Circular*, January 23, 1901.

screen examination or a radiograph. In the method of treating false joints or malunited fractures by "Lane's screws," a Röntgen photograph is of the utmost value in assisting the surgeon to determine before operation the exact length of the screw required in each particular case. By uniting fractures of the leg-bones (such as Pott's) by screws that are too long, serious damage can be inflicted on nerves or bloodvessels unless the surgeon avails himself of the aid of the *x*-rays. The accompanying figure (92) shows that the screw used was of the right length and that the mechanical adaptation of the tibial fragments was satisfactory. Some of the remarks made about 'screwing' apply also to 'wiring' and 'nailing.' Again, the 'screwing' on of a loose fragment offers a promising field for treatment. An excellent case in which sound union of a fractured olecranon was secured in this way was published by the late Mr. Thomas Moore, F.R.C.S.*

A capital account of the history, literature, and present position of 'direct fixation in fractures,' has been published by an American writer, Dr. G. W. Guthrie, of Wilesbarre. He quotes a number of interesting cases of operative fixation of the upper end of the femur, the elbow, and other parts both in recent and in old-standing fractures.†

Where a fracture is attended by such complications as impaction, comminution, multiplicity, interposed tissues, extension into a joint, or dislocation, Röntgen methods afford most useful information. The practical value of the method, however, extends beyond diagnosis, for by further investigation it can be ascertained whether the bones have been reduced to proper position, and whether sound bony union has followed. The progress of a fracture can be followed readily enough when the splints and dressings are translucent to *x*-rays. If it be desired to make periodical examinations through a fixed apparatus, the splints, as already stated, must be made of some penetrable material. The separation of epiphyses, or the so-called 'fracture through epiphyses,' a subject of great importance in surgery, will be dealt with in a separate section (see p. 152).

Where fracture has ended in fibrous union, false joint, or other imperfect result, the exact state of affairs can, with one or two exceptions, be readily found out by radiography. A similar remark applies to a stiff joint after dislocation or other injury. In all these

* *Archives of the Röntgen Ray*, July, 1897.

† *American Medicine*, March 7, 1903, p. 376.

cases important indications may be gained as to the appropriate form of treatment, whether by resection, osteotomy, wiring, refracture, or the breaking down of adhesions.

The exceptions above referred to are chiefly those of fracture or dislocation, or both together, about the shoulder or the hip. In each case an antero-posterior view may be obtained, but a lateral view is occasionally of some use. Thus, the absence of a bone from its socket can as a rule be readily demonstrated, but no lateral record is usually available to show whither it has gone. Under these circumstances, we fall back upon our exact localizing processes, and by means of stereoscopic skiagraphy determine the exact position of the displaced bone.

The diagnostic application of *x*-rays, it may be observed, is likely to do away with much of the time-honoured business of the bone-setters. Professor Howard Marsh and others have pointed out that the greatest successes of these irregular practitioners have been scored in nine cases out of ten by forcible rupturing of arthritic bands. It is now open to everyone to put to an absolute test by means of Röntgen rays the bone-setter's stock assertion that 'the joint is out of place,' or 'the bone not properly set.' In this unexpected way, it is interesting to note, science has cut away the ground from under the feet of the charlatan. Professor Röntgen's discovery thus has dealt the bone-setter a deadly blow that ages of unprofessional protest have failed to accomplish.

In suspected fracture it may be well to bear in mind the figures given by Norris, who found that of 150 cases of pseudo-arthrosis 48 were in the femur, 48 in the humerus, 33 in the leg, 19 in the forearm, and 2 in the jaw.*

To sum up: in dealing with bone injuries successful radiography, compared with previous methods, offers the following advantages: It substitutes speed, accuracy, and finality for delay and doubt; it affords exact evidence that may confirm or modify the diagnosis of the surgeon; it may furnish both grounds for prognosis and hints for treatment; it may save the patient the pain of useless and perhaps dangerous manipulations, as well as the risk of anæsthetics; it provides a permanent record of the precise nature of an injury; it may prove a safeguard for the patient and for his medical attendant, both in the present and the future; and, lastly, it has a special value for teaching purposes.

* *American Journal of Medical Sciences*, January, 1892.

Fallacies.

Many fallacies may arise from an inaccurate relative position of the focus-tube towards the part under examination. By shifting a limb up and down or from side to side, its shape upon the screen may be distorted so as to resemble a variety of deformities. It is well in all cases of supposed injury to make a routine examination of the correspondingly sound side of the body under exactly similar conditions as to relative position of parts and of focus-tube.

Flaws in the sensitized plate or in its development may sometimes lead to an error; and when *x*-ray paper is used a small crease or inequality of surface may result in a perplexing record.

Buttons, coins, or other objects about the person of the patient may cause confusion.

Seiz has pointed out the mistakes that may arise from a misinterpretation of the results of the fluorescent screen. In one case an outward dislocation of both bones of the forearm took place in a girl of thirteen. A radiograph taken twelve days after reduction showed a normal position of joint, but an apparent separation of the tip of the olecranon, of which, however, there was no trace to be found on clinical examination. In a second case the *x*-ray photograph showed what appeared to be a shortening of 3 inches in a fracture of the femur, whereas the clinical measurements proved there was not more than 1 inch of shortening. As Seiz points out, such false impressions might now and then have the greatest importance, especially in actions for damages.

Callus may be pervious to the rays some months after a fracture, and may thus give an impression that there is non-union, whereas the parts may be firmly united.

A fracture without displacement may not show on the *x*-ray photograph, but may often be recognised when viewed from a fresh aspect. Hence it is well to examine first with a screen, so as to determine on the best position for securing an effective record.

It should be borne in mind that in fractures where there is little or no displacement the radiographic evidence may be either slight or altogether absent. The fracture-line of the picture, again, may be obliterated within four to eight or ten weeks by the ossification of the callus. In old fractures there is no fracture-line, but the injury may in many cases be inferred from bony irregularities. Where there is either imperfect ossification of callus or fibrous

union of fragments, as in the olecranon, the fracture may be permanently recognisable by Röntgen methods.

Shepherd* first pointed out, as the result of an experience of his own that the os trigonum tarsi, or intermedium cruris, could be mistaken for a fragment broken from the astragalus. This bone, which is said to persist in about 7 or 8 per cent. of the human species, forms a typical part of the mammalian tarsus. In his excellent book on fractures, Dr. Carl Beck† of New York has brought together the following interesting account of this abnormality:

'The fact that this fracture is not mentioned in any of the text-books of surgery or in special treatises on fractures would easily be accounted for by its only being discovered by dissection; it causes no deformity, and the symptoms it would give rise to during life would be obscure. Shepherd tried to produce this fracture artificially on the cadaver, but "in every case," he says, "where this manœuvre was performed, I failed, even when the greatest force was used, to break off the little fragment of bone mentioned above."

'Pfitzner‡ regards the os trigonum tarsi as an integral part of the posterior process of the astragalus in the adult, which is analogous to the os intermedium antibrachii.

'The practical significance of this bone is evident from a case described by Wilmans,§ which is also highly interesting from a medico-legal standpoint:

'A labourer claimed that he was injured by an iron bar on January 20, 1897, but was able to work during the whole day. On the following day he called upon Dr. Wilmans, complaining of intense pain in his internal malleolus. He limped, and asserted his inability to work. Wilmans found a slight swelling below the right internal malleolus. Ecchymosis of the skin being absent, the swelling was attributed to the presence of a considerable degree of talipes, from which the labourer suffered at the same time. The leg was elevated, and fomentations were applied for several days. The labourer still complaining of great pain, it was decided to transfer him to a hospital for observation. When discharged after

* 'A Hitherto Undescribed Fracture of the Astragalus,' *Journal of Anatomy and Physiology*, October, 1882.

† 'Fractures,' Carl Beck, M.D. Saunders and Co., Philadelphia, 1900.

‡ 'Beiträge zur Kenntniss des menschlichen Extremitaätenskelets, morphologische Arbeiten,' 1896, 2 tes Heft.

§ *Fortschritte auf dem Gebiete der Röntgenstrahlen*, Band ii., Heft 3.

several weeks of treatment, the patient made an effort to resume work, but at once declared that he was unable to keep it up. He was therefore admitted to another hospital, where he repeated this manœuvre several times during a period of six months. Finally, he claimed damages for having been crippled by the injury sustained on January 20, 1897; but in view of the negative objective condition found by Dr. Wilmans the society decided not to grant any claims. The consequence was that the labourer was transferred to the surgical division of a third hospital for further observation. There he complained that he had continuous pains below the right external malleolus, even while in the recumbent position. The pain increased while walking or sitting. Stepping on the right heel he also declared to be impossible. By distracting his attention, however, it was noticed that he could stand well on his heel, and he would undoubtedly have been declared a malingerer had not the Röntgen rays come to his rescue—at least, temporarily. A skiagraph showed a bone fragment at the junction of the astragalus with the posterior surface of the calcaneum. On the strength of this skiagraphic "proof," Dr. Wilmans, although still mistrusting, was forced to modify his original opinion, and certified that the patient suffered from "fracture of the astragalus, in consequence of which he was damaged for life." The labourer therefore received an annuity of 30 per cent. in proportion to the estimated curtailing of his wages.

'Soon afterward the labourer was discovered by Dr. Wilmans carrying a heavy weight without any apparent pain, while formerly he had claimed to be unable to walk without a cane or a crutch. Dr. Wilmans insisted upon a second irradiation, this time also skiagraphing the uninjured left foot. The skiagraph showed the "severed bone fragment," which had first been regarded as a sesamoid of the musculus flexor longus hallucis, but which was now recognised as a normal os intermedium cruris. The society, of course, refused the annuity, and the German Supreme Assurance Court, to which the labourer had appealed, not only sustained the verdict of the society, but also decided that the labourer must return the annuity which he had unjustifiably enjoyed for eighteen months.'

It may be noted, with regard to the above interesting case, that surgeon, society, and court all appeared to have attached an exclusive and conclusive value to fracture. Clearly, bone disease

resulting from injury and damage to soft parts would not be shown by the rays except as an extremely rare occurrence.

Mr. C. H. Golding Bird* has pointed out some of the fallacies of radiography in relation to fractures. While deprecating the use of the *x*-rays in all fractures, he advocates their use when the surgeon requires more exact information in any particular case, and where the nature of the injury is doubtful. The second class includes those of the fibula, vertical and transverse fractures in any situation, and certain fractures about the hip. He urges that radiography should be regarded as a subsidiary agent to diagnosis, and its evidence in cases of doubt and difficulty should be received *with caution, and only after due interpretation by someone whose experience warrants his speaking with authority.*

In answer to the question whether the rays can show a fracture where none exists, he mentions:

1. Epiphyseal lines—*e.g.*, lower end of ulna.
2. The light interval of a joint—*e.g.*, elbow over olecranon.
3. Acromio-clavicular joint resembling fracture.

Special Fractures.

Fractures of the scapula that may be detected by ordinary manipulation need not be considered here. Sometimes, however, an injury of the kind is exceedingly obscure, in which case a Röntgen ray examination might disclose its real nature. For instance, it would be difficult or impossible in any other way to diagnose the rare fracture of the glenoid cavity from dislocation of the head of the humerus or fracture of its anatomical neck.

Fractures of the collar-bone can be readily shown by the rays, but as a rule there is little information to be gained in that way that could not be acquired by simpler methods of examination. An exception may, perhaps, be made in the case of the break without displacement that sometimes occurs between the attachments of the conoid and the trapezoid ligaments. Such a case was reported by Dr. Richardson:† 'A football player of nineteen injured his left shoulder. Six hours after the accident tenderness was found at the outer end of the clavicle, but neither crepitus nor deformity was to be made out. The Röntgen rays showed a

* *British Medical Journal*, June 8, 1901, p. 1390.

† *Boston Medical News*, December 26, 1896.

solution of continuity at the point of tenderness, where a week later callus appeared.'

Fracture of the Humerus.—This bone is readily photographed throughout its length by the Röntgen methods, which are of special value in determining the nature of obscure injuries at its upper and lower ends. The exact diagnosis of fractures about the head, as every surgeon knows, is often attended with great, if not insuperable, difficulty, especially when there is much swelling. Incomplete separation of the head of the humerus at its junction with the shaft has been reported in cases that had been regarded as sprains before the Röntgen examination, and it seems not unlikely that such injuries may prove less rare than has been hitherto suspected. So, too, fissures due to direct violence have often been observed in cases which, were it not for the Röntgen rays, would have been classified as bruising of the soft tissues. In a case under Mr. Lynn Thomas, a comminuted fracture of the surgical neck, it would formerly have been impossible to make out the precise nature of injury.

Old Green-stick Fracture of the Humerus.

A curious case of this kind has been reported by Mr. E. W. H. Shenton,* of Guy's Hospital.

The injury was of three years' standing before its nature was cleared up by the Röntgen rays. Those who previously examined it said unhesitatingly that both the bones of the forearm were dislocated outwards, but the curious point was that the movements of the joint were quite perfect.

The explanation furnished by the radiogram was that the external condyle remained in its proper place while the articular surface was 'skewed' inwards. The fracture must have been undiagnosed at the time, and had the Röntgen rays been available the patient might have been saved the deformity.

Fractures about the elbow are often attended with such rapid swelling that, unless seen at once, it is in many instances impossible to ascertain the extent of the injury for several days. Indeed, it is hardly too much to say that under such circumstances a Röntgen photograph of the swollen elbow is absolutely the only means of exact diagnosis at the command of the surgeon, who may in this way save much valuable time and anxiety. For instance the

* E. W. H. Shenton, *Physician and Surgeon*, March 22, 1900.

damage may be of such a kind as to demand prompt excision. In any event, the *x*-rays will indicate whether the line of fracture at the lower end of the humerus is (*a*) transverse, (*b*) T-shaped, (*c*) through condyles, (*d*) through epiphyses, and whether it is complicated by (*e*) dislocation or (*f*) fracture of the olecranon. In this way the surgeon can inform the patient forthwith as to the probable duration and result of treatment. Moreover, from the knowledge gained as to whether the fracture is extra- or intra-capsular, he will

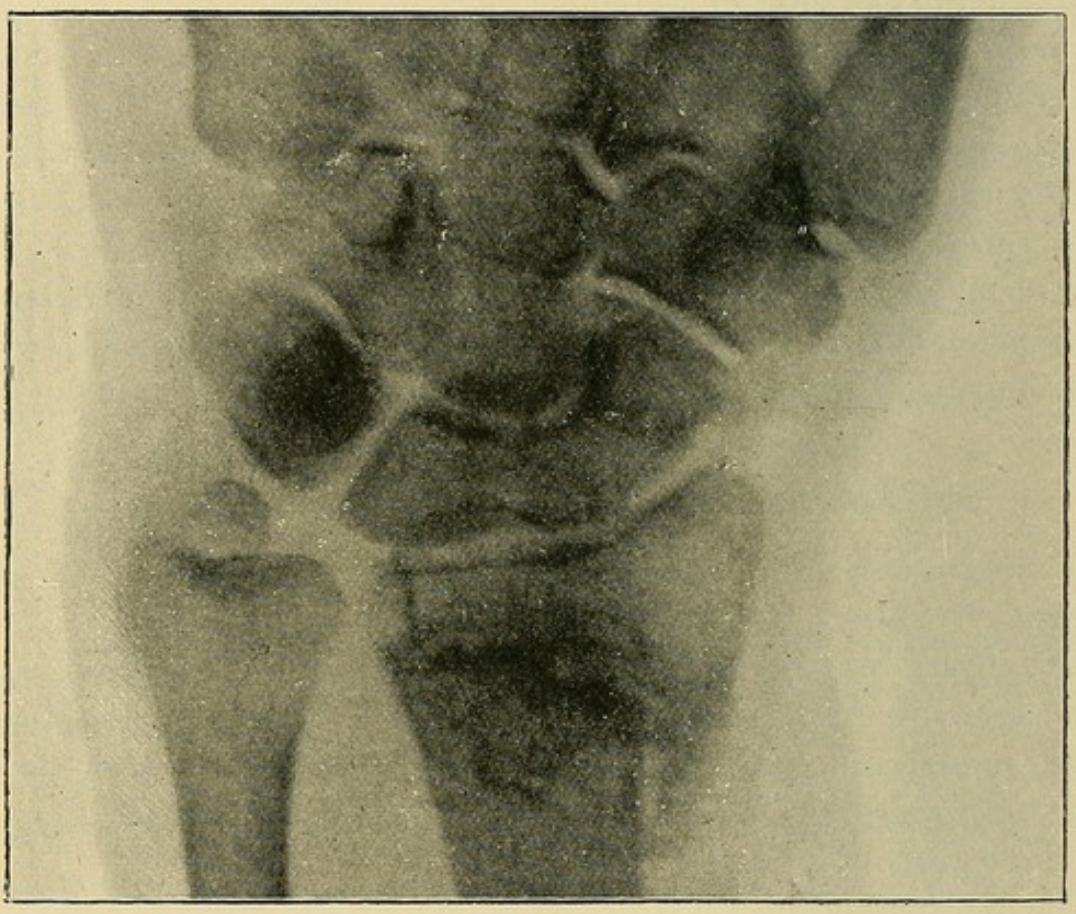


FIG. 93.—COLLES'S FRACTURE, WITH RUPTURE OF RADIO-ULNAR LIGAMENT.

J. Lynn Thomas.

know exactly when to begin and when to avoid early passive movements. Thus, if the break be transverse, above the capsule, such exercise can be delayed for a month or more, 'as there is then no danger of a stiff joint, but a risk of the passive movements at the seat of fracture leading to a false joint' (Walsham). Other authorities would, however, with Lucas Championnière,* advocate immediate massage, together with mobilization. Indeed, the advantages of Röntgen's method to the practical surgeon are nowhere more apparent than in obscure injuries to the elbow-joint.

* 'Traitement des Fractures par le Massage et la Mobilisation,' 1895.

Fractured Olecranon.

Mr. F. D. Bird has published a radiogram showing the advantages of open suture in fracture of the olecranon. The accident had taken place three months before the operation, and the arm was almost useless. A thin slice was sawn off each of the fragments, which were

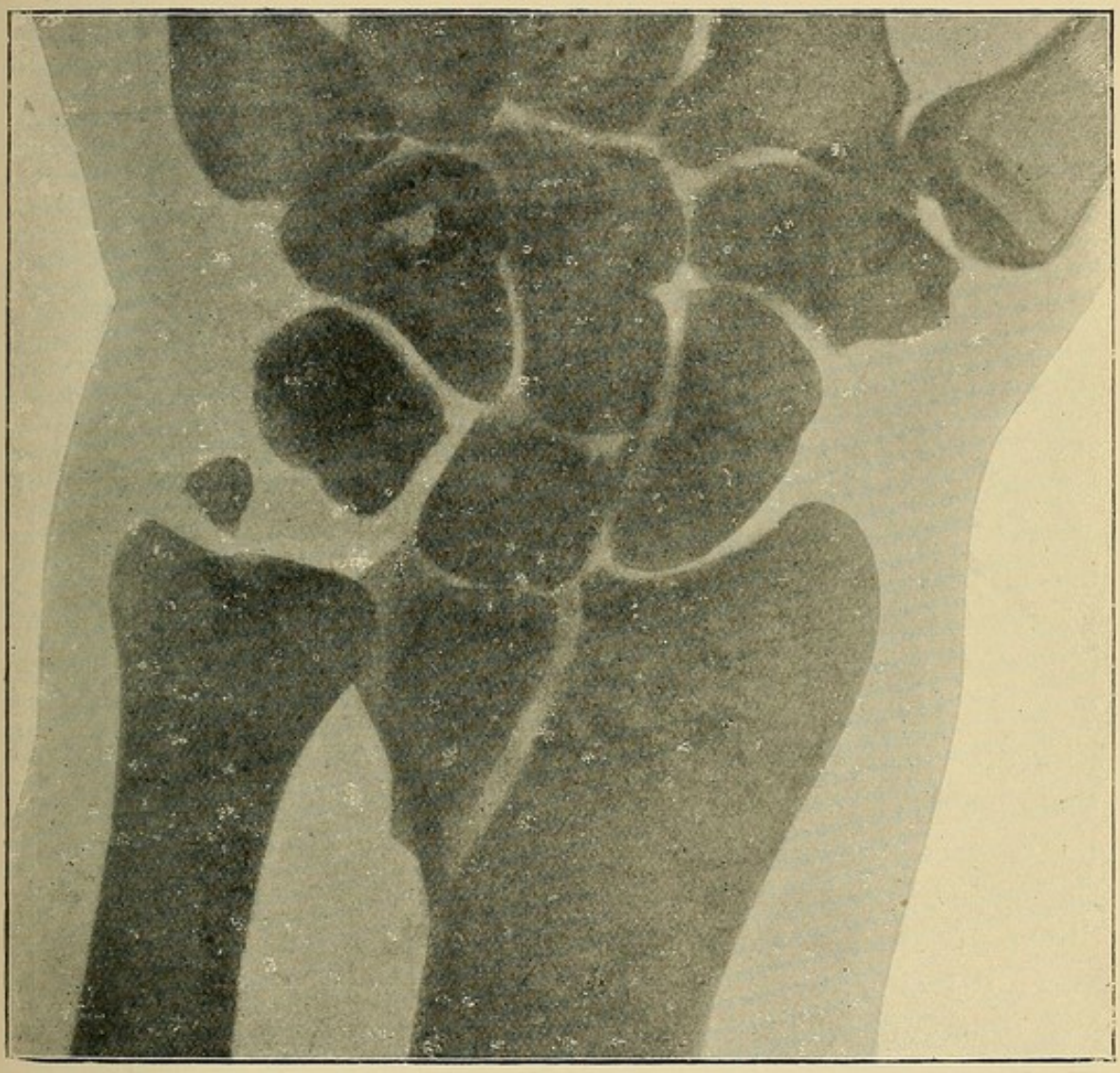


FIG. 94.—DOUBLE COLLES'S FRACTURE SHOWING LONGITUDINAL FRACTURE OF RADIUS WITH SLIGHT IMPACTION AND FRACTURE OF STYLOID PROCESS OF ULNA.

J. Lynn Thomas.

then brought together by platinum wire passed through them from side to side. That method, in the opinion of the operator, gives a better grip and more accurate approximation than vertical sutures.

Mr. Shenton* mentions a case in which the olecranon was not only completely severed from the shaft of the ulna, but was also

* E. W. H. Shenton, *Physician and Surgeon*, March 22, 1900.

fractured vertically. He suggests that perhaps a more valuable use of the Röntgen method than the power of actual diagnosis is the facility it presents for watching the progress of a fractured olecranon as regards recovery.

In one published case a lady cyclist fell while dismounting from her machine; her elbow was injured, and the dislocation diagnosed and reduced. After months of persevering exercise movement was restored; but a hard lump could be felt in front of the joint, the nature of which was open to speculation. On being examined by the Röntgen rays, the cause of the lump became apparent in a splinter of bone an inch and a half long embedded in the muscle. This bony fragment had evidently come from the humerus; at the same time the head of the radius showed an impacted fracture. Neither fracture had been diagnosed at the time by the surgeon who attended the case.*

Fractures about the middle of the forearm are readily accessible to the rays, the information derived from which may be applied upon general principles. However, so far as the pathology of frature of the lower end of the radius is concerned, the method has already demonstrated a number of fresh facts. Mr. Lynn Thomas† published the instructive case of a patient with double Colles's fracture. From a clinical point of view the lesion appeared to be identical on both sides, but Röntgen photographs showed a wide difference in the bone injuries. In each the styloid process of the ulna was fractured at its base, an event formerly described by surgical authorities as somewhat rare. One wrist showed the ordinary fracture of the lower end of the radius, with outward displacement; the other (Fig. 94) slight impaction of the radius about $\frac{3}{4}$ inch from its lower end, to be detected by noticing the irregularity on the ulnar side of the bone. By the side of and near that projection is a 'complete longitudinal single fracture of the lower end of the radius, showing a detached portion of a triangular shape in its normal position attached to the radio-ulnar ligament.' In a later communication to the same journal, the author expressed an opinion that 'the true pathology of one of the commonest of fractures (*i.e.*, Colles's) requires rewriting in the leading surgical text-books in the English language.' In 1899, thanks to *x*-rays, one can state that fracture of the ulnar styloid process

* *New York Medical News*, February 23, 1901, p. 286.

† *British Medical Journal*, January 2, 1897.

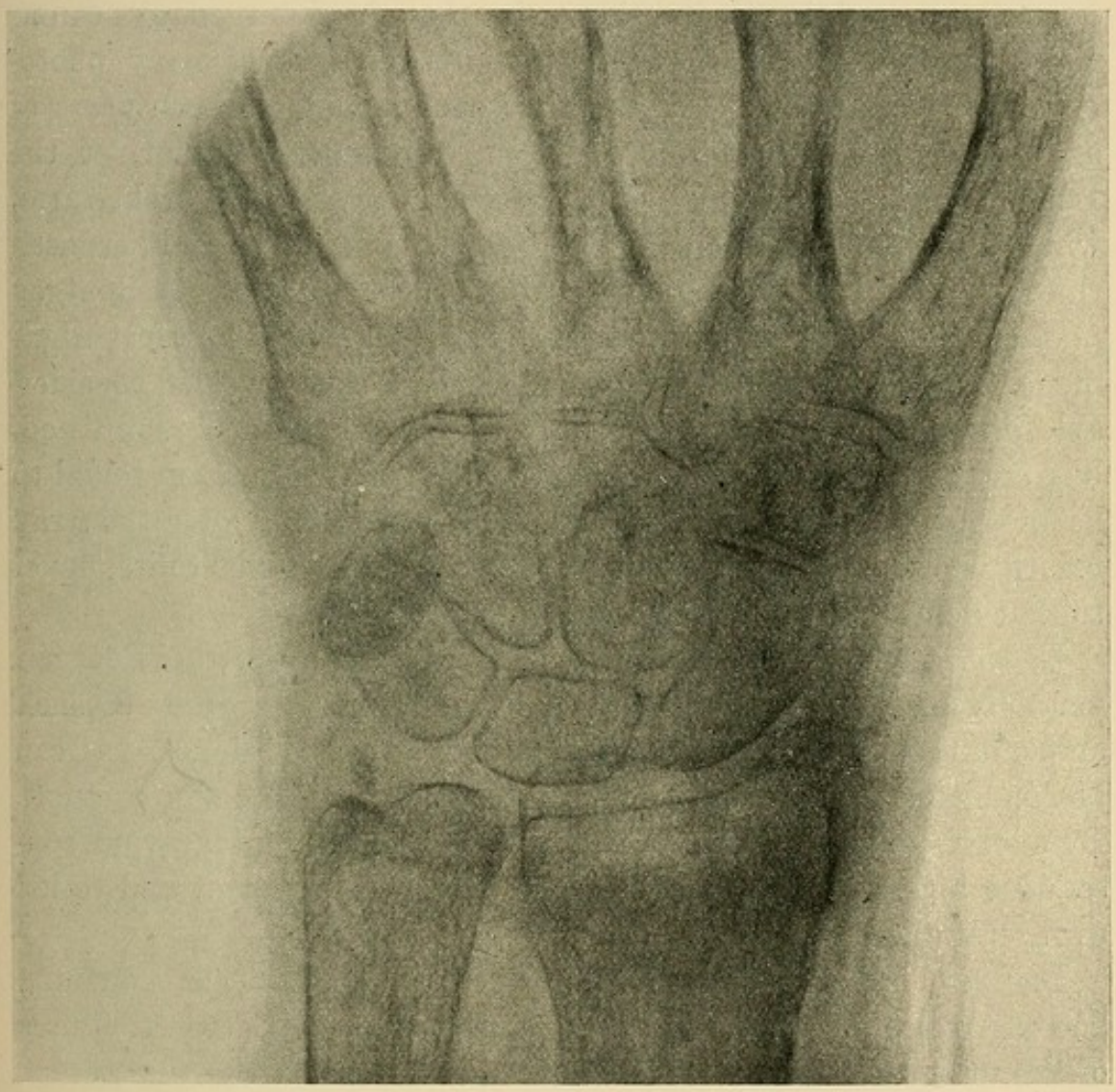


FIG. 95.—RARE CHANGE IN BONE THREE MONTHS AFTER COLLES'S FRACTURE.
Dr. D. Morgan,

usually accompanies injuries to the radius in Colles' fracture in between 60 to 70 per cent. of the cases.

Mr. Thomas has placed another interesting case (Fig. 93) on record. In his opinion 'this illustrates the rupture of the radio-ulnar ligament described by Mr. Clement Lucas in Guy's Hospital Reports for 1884.'

Two illustrations shown in former editions of this book furnish a good example of the diagnostic service that the Röntgen rays can at times afford. They were taken in the early days of *x*-ray photography from a restless and muscular young man, eighteen years of age, under the care of Mr. Jonathan Hutchinson, junior, at the London Hospital. The patient presented himself with a broken arm, which had been put up in splints a few days before at another institution, and which he imagined was not going on well. A Röntgen photograph proved double fracture, with both bones in perfect alignment. When he returned a week later, the rays revealed considerable displacement.* The broken bones were thereupon readjusted, but at the end of another week the fragments were again found to be overriding. The limb was reset, and ten days later the *x*-ray record showed union in good position, almost, but not quite, equal to that demonstrated in the first photograph.

In the after-treatment of a restless patient, then, the Röntgen methods may prove of constant value. Even if the results of such an examination be negative, no harm will have been done, as it can be conducted without taking off a single splint, dressing, or garment. By availing himself of its aid, the surgeon may possibly avoid consequences dangerous alike to the welfare of his patient and to his own reputation.

Destot† has described fractures of the scaphoid, os magnum, and styloid process of the ulna, associated or not with fractures of the radius. Of the latter, he has identified with the fluoroscope three chief types: (1) The epiphysis is entirely detached, and, strictly speaking, there is no interarticular fracture. (2) The fragment is wedge-shaped at the expense of the posterior aspect of the radius, the front of which retains its position. This type shows many varieties, as when the fragments are multiple or displaced from without forwards, when the fissure extends higher

* The photographs were taken through splints and clothing. In the first the grain of the wooden splint could be traced.

† 'Radioscopie Clinique,' Régnier, p. 54.

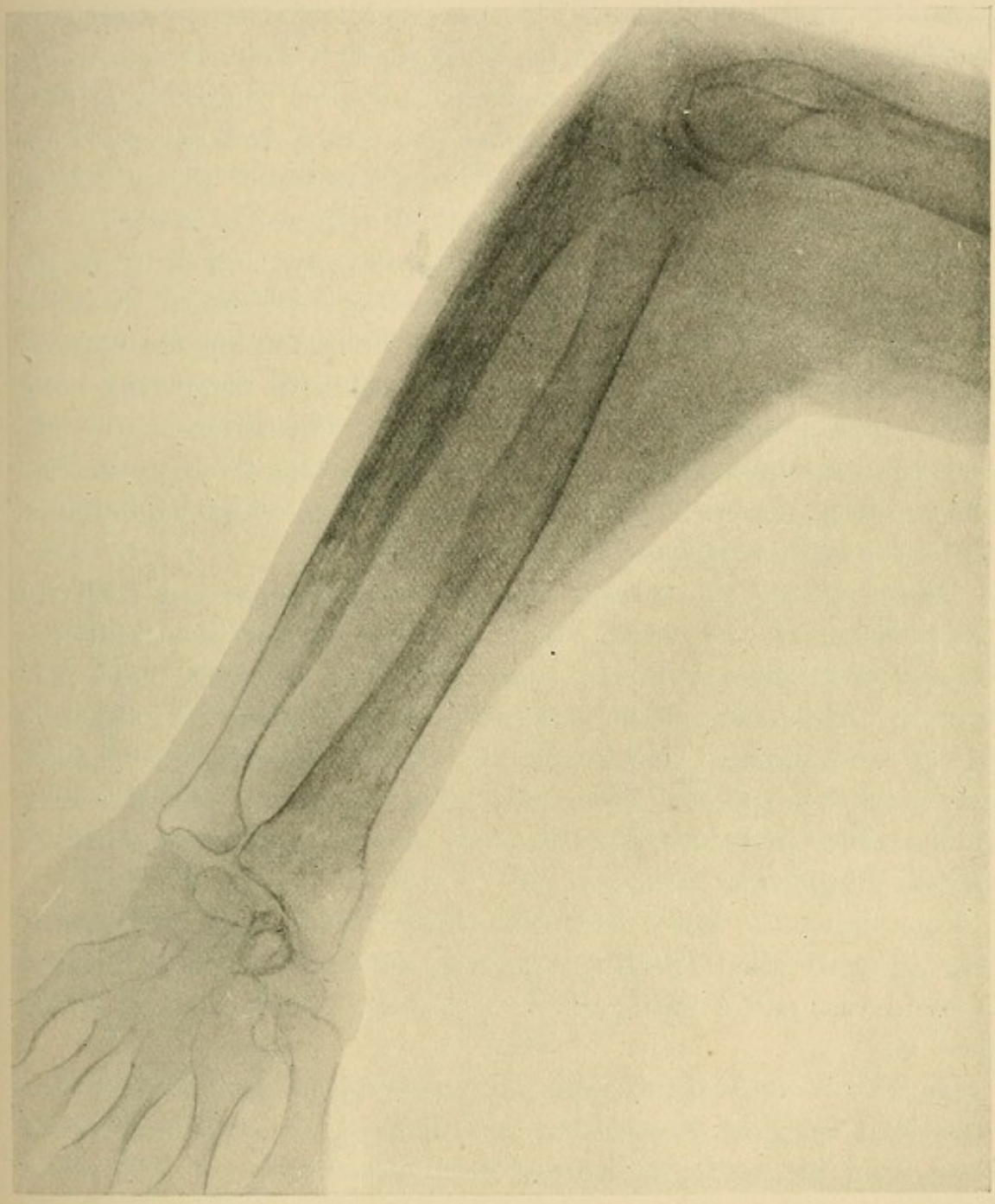


FIG. 96.—COLLES'S FRACTURE WITH SEPARATION OF STYLOID. TRANSPARENCY OF BONE, PROBABLY DUE TO ABSORPTION OF LIME SALTS; CLINICALLY RESEMBLES OSTEOMALACIA.

Dr. D. Morgan.

or lower, involving the posterior lip only, or the epiphysis only. Special attention was drawn to this particular kind of fracture in the pre-Röntgen-rays day by Dr. Rhea Barton in 1838,* and Hamilton, in his treatise on Fractures and Dislocations, designates it 'Barton's fracture' in contradistinction to a Colles's fracture. It is interesting to observe that many pathological conditions of bone lesions, which were hitherto known only to a few experts, have been again prominently brought before the notice of the profession from observations made by means of the *x*-rays. It is always advisable to radiograph obscure bone injuries, and not to trust the fluoroscope alone, because the former method will record what the eye cannot see in the latter: the one is like counting the stars of the Pleiades with the naked eye, and afterwards comparing notes with a photograph of the same region. (3) The anterior and posterior lips are broken off, and the shaft penetrates them, separating the one from the other, the bones being all more or less comminuted and more or less displaced on the outer side.

Destot points out several possible fallacies connected with the examination of the wrist. The shadows of the bones do not exactly correspond with the appearance on a skeleton; one may confuse a dislocation of the first row of carpal bones with a fracture of the os magnum. The scaphoid, instead of being boat-shaped, may present a globular form crossed by a shadow, and due to a subluxation. Fracture is present only when a clear space separates the two fragments.

Fracture of the lower end of the radius with anterior displacement, the so-called 'Smith's fracture,' is described with illustrations of cast and a radiogram by Dr. John B. Roberts,† of Philadelphia.

He refers to a monograph on the subject presented to the American Surgical Association in 1896, recording a number of cases from his own practice and from other sources. The radiogram is that of an old case, and shows the prominent lower end of ulna projecting, so to speak, over the displaced carpus.

Fractures of the hand can be readily demonstrated by means of the Röntgen rays. A break of the fourth metacarpal, not an uncommon injury, is sometimes difficult to diagnose by ordinary methods. An *x*-ray examination at once reveals an injury of that kind, and has often disclosed simple longitudinal fissures in bones

* *Philadelphia Medical Examiner*, 1838.

† *Philadelphia Medical Journal*, March 9, 1901, p. 482.

said to have been bruised. In the case of the Poor Law Medical Officer, who is paid on a higher scale for attending fractures, the possibility of proving the existence of such obscure injuries presents a distinct economical advantage. To a less extent a similar remark applies to all who are engaged in surgical practice, whether special or general.

The illustration portrayed in Fig. 97 shows the results of a cog-wheel accident fourteen years previously. The metacarpal bone of the forefinger has been apparently broken into two main pieces which lie at a cross-angle of about thirty degrees. The irregular shape of the lower fragment probably results from chronic periostitis and osteitis following the injury. Between the two fragments there appears to be a kind of false joint. The middle joint of the forefinger is partly obliterated by what seems like bony union. The sesamoid bone opposite the distal end of the thumb metacarpal has apparently become united to the latter by a more or less ossified ligament. The original photograph, kindly lent to the writer by Dr. J. R. Philpots, of Parkstone, shows some good records of muscles and other soft structures. Thus, in the outer side of the little finger metacarpal may be traced the abductor and flexor brevis muscles. On the outer side of the middle joints of the second and third fingers are what appear to be the lateral expansions of the common extensor of the digits. Along the back of the bones of the metacarpal and phalanges of the thumb the extensor tendons can be clearly traced. The tendon of the extensor secundi internodii, indeed, can be followed up to its insertion at the base of the terminal phalanx. Unfortunately many of the fainter records are lost in reproduction.

Hand.

As anticipated, the Röntgen ray methods have shown that metacarpal fractures are more common than was formerly supposed. There is usually little displacement, since the adjoining metacarpal bones act as efficient splints.

In some cases where there is lateral displacement, union in a bad position may lead to much deformity and loss of function. Reduction is always easy if the exact nature of the injury be known; it is therefore desirable in such cases to examine the fracture by means of the Röntgen rays.

A good account of this injury is given by Dr. Carl Beck,* of

* 'Treatment of Fracture of the Metacarpal Bones,' Carl Beck, M.D., *New York Medical Journal*, August 4, 1900, p. 177.



FIG. 97.—DEFORMITY AFTER COG-WHEEL ACCIDENT.

New York. He describes a case in which a man sustained fracture of the fourth metacarpal in striking a blow with his fist.*

Dr. Beck treats these fractures by a simple splint made of two rubber drainage-tubes lightly pressed into the adjoining interosseous spaces, and kept in position by strips of plaster passed round the hand.

Dr. G. T. Beatson, of Glasgow, has published an excellent illustration of the so-called 'stave of thumb,' or Bennett's fracture. The fracture is an oblique detachment of the palmar half or more of the articular surface of the metacarpal bone facing the trapezium, while, in addition, the entire metacarpal bone, except the little piece of the base so separated, has slipped backwards, no doubt through the action of the extensor ossis metacarpi and other muscles, and this simulates a dislocation of the bone in that direction.

In his original description Professor E. H. Bennett, of Dublin, says that fracture of the metacarpal bone is more common than that of any other of the metacarpals; and, further, that when the fracture occurs in the metacarpal bone of the right thumb, it is not just above the middle, as is usually asserted, but that it is situated at the base of the bone. The injury simulates dislocation, and is commonly regarded as a sprain of the thumb. When untreated, after a long period of disability it unites with slight deformity.

Simple Fracture—First Phalanx.

So far as we know, this injury appears to be rare apart from compound fracture.

A case is reported by M. Estrabaut† of a man whose forefinger swelled considerably after striking another man with his fist. A radiogram showed an L-shaped fracture involving half the articular end of the first phalanx and extending thence obliquely down the shaft of the bone.‡

The following excellent summary of fractures of the carpus has been kindly written by R. Higham Cooper, Esq. It is founded on an extensive recent experience as assistant in the Electrical and Röntgen Department of the Charing Cross Hospital, London.

* For abstract of case, with illustrations, see *Medical Review*, November, 1900, p. 687.

† *Gazette des Hôpitaux*, August 9, 1900, p. 909.

‡ For radiogram, see *Medical Review*, October, 1900, p. 629.

Fractures in the Carpus.

'One or more of the carpal bones is occasionally broken by direct violence, usually accompanied by much crushing of the wrist. The bones more commonly fractured are the scaphoid, semilunar, and os magnum; it is obvious that they are usually complications of some fracture of the lower extremity of the radius. The facts of the difficulty of diagnosis by palpation, and the little importance of the diagnosis from the point of view of treatment, has, in my opinion, led surgeons to believe them to be more unusual than is really the case. In the course of three years, during which time I have taken special care to skiagraph every case of injury to the wrist, I have succeeded in collecting twenty-two cases in which fracture of the scaphoid has occurred. Seven of these were uncomplicated by any other bony lesion, two were accompanied by fracture of the semilunar, and the remainder by a Colles's or other extensive injury. Another factor in the overlooking of these fractures may be found in the want of a thorough skiagraphic examination. Many of these cases showed no bony lesion under the fluorescent screen; this shows the importance of never accepting a negative diagnosis from the screen: photographs should always be taken. Several of my friends doing *x*-ray work at the various hospitals have come to the same conclusion as my own; one of them, for instance, collected nine cases of fractured scaphoid in a little over a year. These fractures occur usually in the transverse axis of the bone across its narrowest part, but longitudinal fissures are sometimes found. They are seldom comminuted unless there is considerable crushing, though I have seen a case of Colles's fracture in which the scaphoid and semilunar were each in several fragments, one penetrating the wrist-joint.

'The bones of the metacarpus and the phalanges are quite commonly broken, either by indirect or direct violence. Fracture of a terminal phalanx is nearly always due to direct violence. The accompanying skiagram shows one of these cases. The patient was Sir Conan Doyle, who had a blow from a cricket-ball whilst batting. A point of interest about this fracture is that, though so evident on the plate, it was missed in the screen examination. The skiagram is mounted stereoscopically' (Fig. 98).

An excellent monograph on the radiography of injuries of the

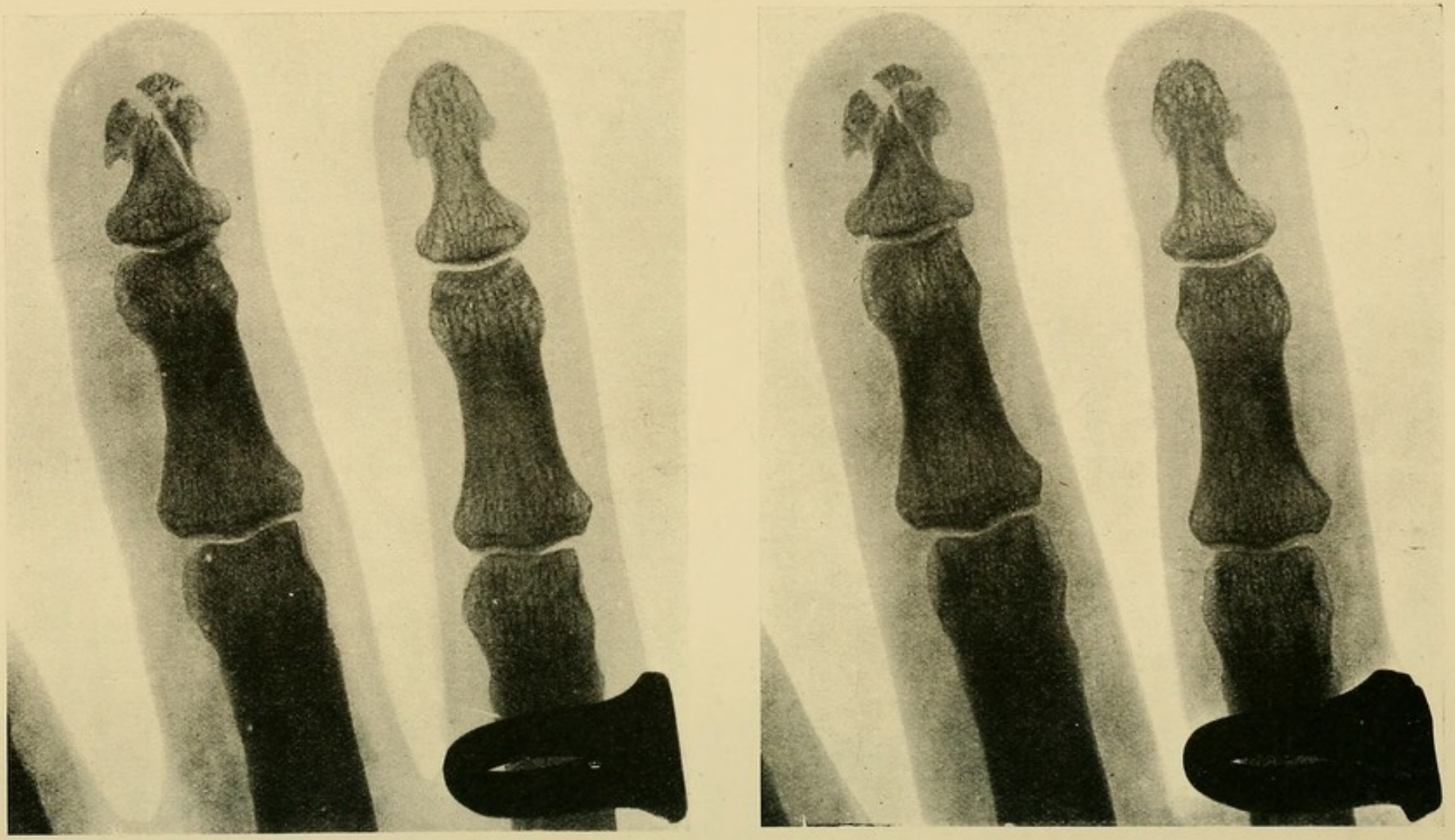


FIG. 98.—STEREOSCOPIC VIEW OF FRACTURED TERMINAL PHALANX (SIR CONAN DOYLE'S HAND).

Dr. H. Cooper.

(Directions : Look steadily at the central point between the two fractures ; squint inwards until there are three fractures ; look steadily at the central one, and it will quickly stand out in relief.)

wrist has been written by Dr. Destor.* Within nine years he has radiographed no less than sixty-four fractures of the scaphoid. Most of them were old cases that had escaped diagnosis. This injury is constantly mistaken for sprain, and the resulting deformity to rheumatism and rheumatoid changes. Other carpal injuries include dislocation of the first row of carpal bones, medio-carpal dislocation, fractures of the semilunar cauliform and os magnum. In old cases where anchylosis is completed and there is much disability or deformity he advocates excision of the wrist.

In fractures about the pelvis, we can now obtain excellent radiograms of any part of the ilium, pubes, or ischium ; fissures of the ilium, for instance, extending into the sacro-iliac synchondrosis may be as clearly demonstrated as the fissures in the lower end of the radius. For such successful results, it is usually essential to have an induction-coil giving not less than 18 inches spark, and also a focus-tube with a water-cooler to withstand the powerful bombardment of the cathode rays against the anticathode.

Speaking generally of fractures of the bony ring of the pelvis, the nature of the injury may usually be diagnosed without the Röntgen methods. As a rule the complications are of far greater importance than the fracture itself. Mr. H. L. Barnard† has described a case in which an *x*-ray photograph revealed a vertical fracture of both rami of the left pubic bone in a child who had been run over, and who showed a large hæmatoma in the left groin. Partial fractures of the pelvis are not usually of any great importance.

Fractures of the Neck of the Femur.

These injuries are of a diverse nature, and exact diagnosis may be obtainable only on the evidence furnished by a radiogram. A good record may sometimes be secured even under adverse circumstances—as, for instance, in stout persons.

It will be specially wise whenever possible to secure a record of impacted intracapsular fracture of the hip, because of its frequent after-shortening, which may be attributed by patients to unskilful treatment. Under such circumstances a differential photograph, showing an alteration in form or relation of the injured side, might be of the utmost value to the medical attendant.

* 'Le Poignet et les Accidents du Travail,' Dr. Destor. Paris : Vigot Frères, 1905.

† H. L. Barnard, F.R.C.S., 'Fractures of Lower Extremity : *Practitioner*, October, 1901, p. 388.

It may be as well to note here the kind of injuries most commonly met with at various ages.* Barnard gives them as follows: 'If we accept Royal Whitman's statement (*Annals of Surgery*, February,

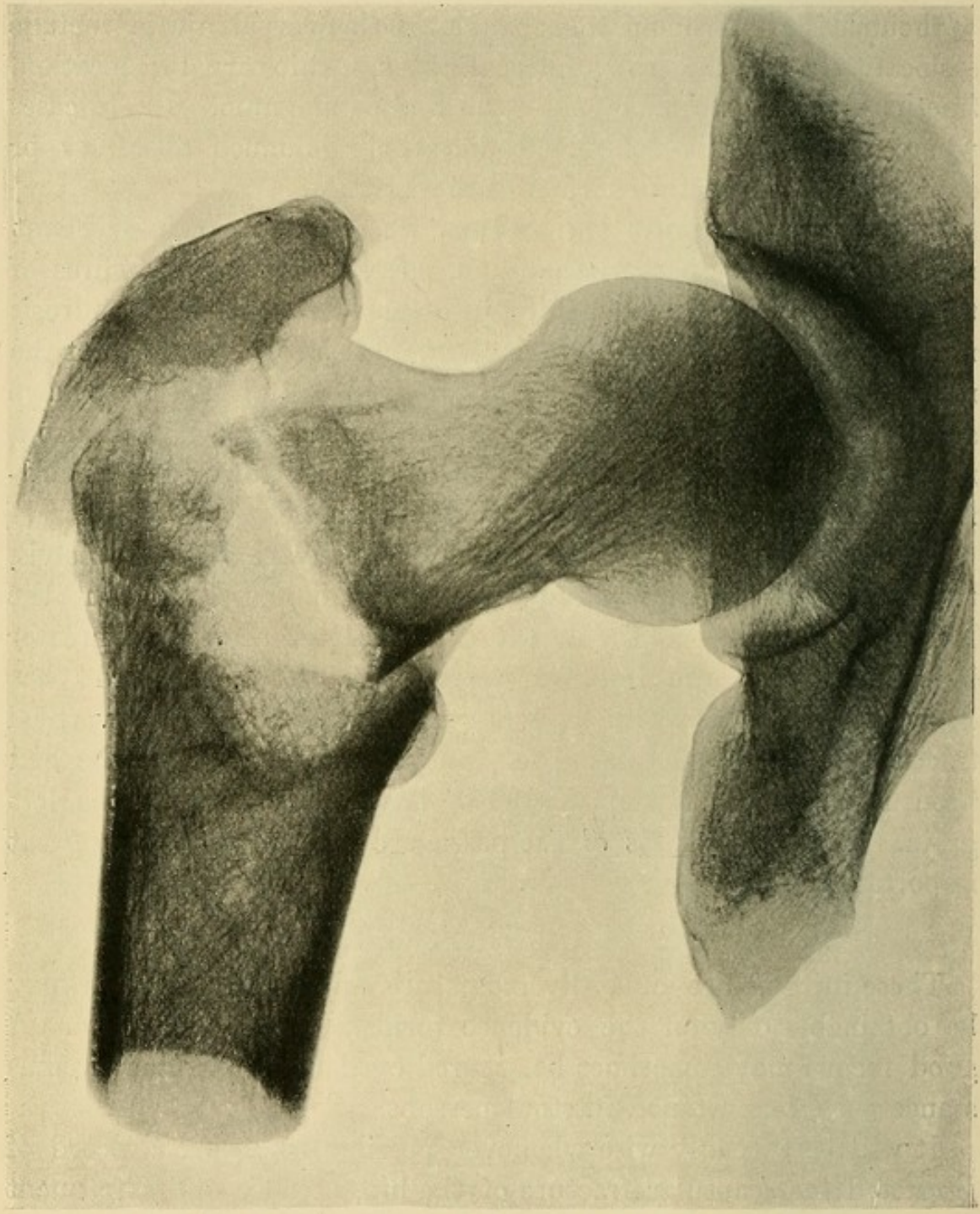


FIG. 99.—EXTRACAPSULAR FRACTURE OF NECK OF FEMUR.
[Mr. Robert Jones's case. Radiographed by Dr. Morgan.

1900, vol. xxxi., p. 145) that injuries of the neck of the femur in children under ten are fractures, and that it is not until the age of puberty that the epiphysis is sufficient of an entity to be separated,

* *Loc. cit.*, p. 394.

then we have a very interesting age-classification of injuries to the neck of the femur:

1. Fracture of the neck (Whitman)	...	2—10 years.
2. Separation of epiphysis ...	...	15—18 „
3. Coxa vara (traumatic) ...	...	2—18 „
4. Extracapsular fracture of the neck, about		30—40 „
5. Intracapsular fracture of the neck	...	50—70 „

Coxa Vara.—Mr. Lynn Thomas has communicated the case of a young man aged about eighteen, who injured his hip in playing football. From an examination of his signs and symptoms, some months after the original injury, he would have concluded that absorption was taking place of the head of the bone, most likely after impaction into it of the neck. An examination by the *x*-rays, however, showed the bending of the neck of the femur to be one of coxa vara. It is waste of time to try and radiograph the hip in adults if one does not possess a 'hard tube.'

In extracapsular fracture of the hip (Fig. 99) the rays may show conclusively whether the neck of the bone is impacted or not in the great trochanter, especially when a comparison is made with a photograph of the sound side. The knowledge thus gained, whether negative or positive, could not fail to be helpful to treatment, inasmuch as extension is contra-indicated in the impacted variety. Moreover, it would guide the prognosis as to permanent shortening and stiffness of the joint. Generally speaking, a fracture can now be readily enough demonstrated by the Röntgen rays in all parts about the hip. Two forms of *Intracapsular fracture* are well shown in Fig. 100.

In fractures of the shaft of the femur the value of the radiograph will lie chiefly in its evidence as to the proper setting and subsequent union of the broken ends. A good example of malposition and false joint in this bone has been kindly placed at the writer's disposal by Mr. Robert Jones (see Fig. 101).

In fractures of the lower end of the thigh-bone *x*-rays are likely to be more useful. Injuries about the knee are apt to cause rapid swelling in and around the joint, so that a thorough examination by ordinary methods is out of the question. Then it is that a confident appeal may be made to the Röntgen method. Without taking off a splint or dressing, we may expect to ascertain one or more of the following conditions: (*a*) line of fracture, whether

olibque, transverse, comminuted, or T-shaped; (*b*) implication or otherwise of joint; (*c*) separation of epiphysis.

Fracture of Patella, or Knee-cap.—Unless the patient be seen at once after this accident, the parts often become so swollen that it is impossible to diagnose the injury. For the investigation of such a case the Röntgen rays are specially adapted. They will reveal not only complete fractures, but also incomplete—that is to say, where the starred or fissured fragments are kept in position by the aponeurosis. As regards after-treatment, the surgeon will be

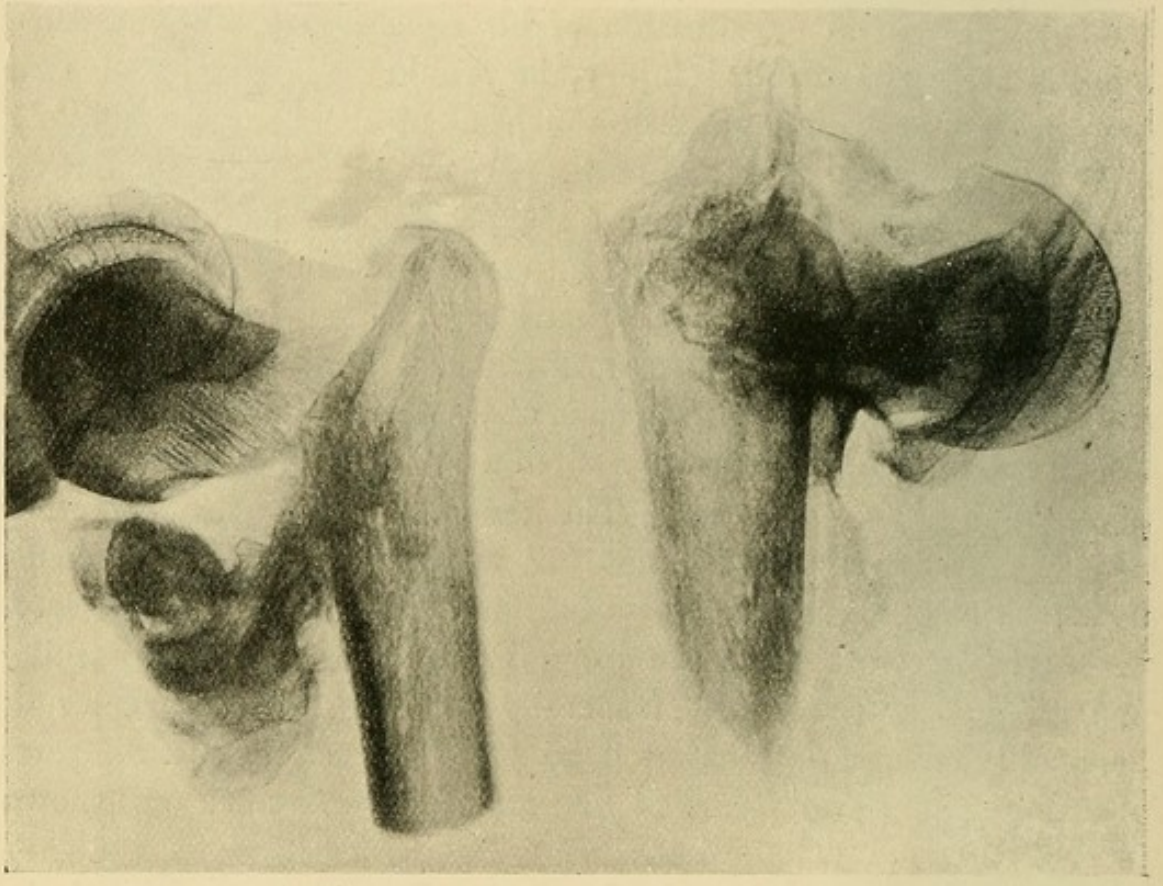


FIG. 100.—INTRACAPSULAR FRACTURES OF NECK OF FEMUR.
Mr. Robert Jones. Radiographed by Dr. Morgan.

able by means of a radiograph to determine whether his methods have brought the patellar fragments into good position. Here, too, the results of wiring can be closely followed.

Some years before the introduction of the Röntgen methods the following case came under notice: A patient injured her knee, and a medical man who was called in diagnosed dislocation of the semi-lunar cartilage. A few months later, the joint being stiff, a surgeon administered chloroform and flexed the limb in order to break down adhesions. After this procedure the knee-cap was found broken.

The contention of the surgeon was that the first examination failed to detect an incomplete fracture, which his subsequent manipulation

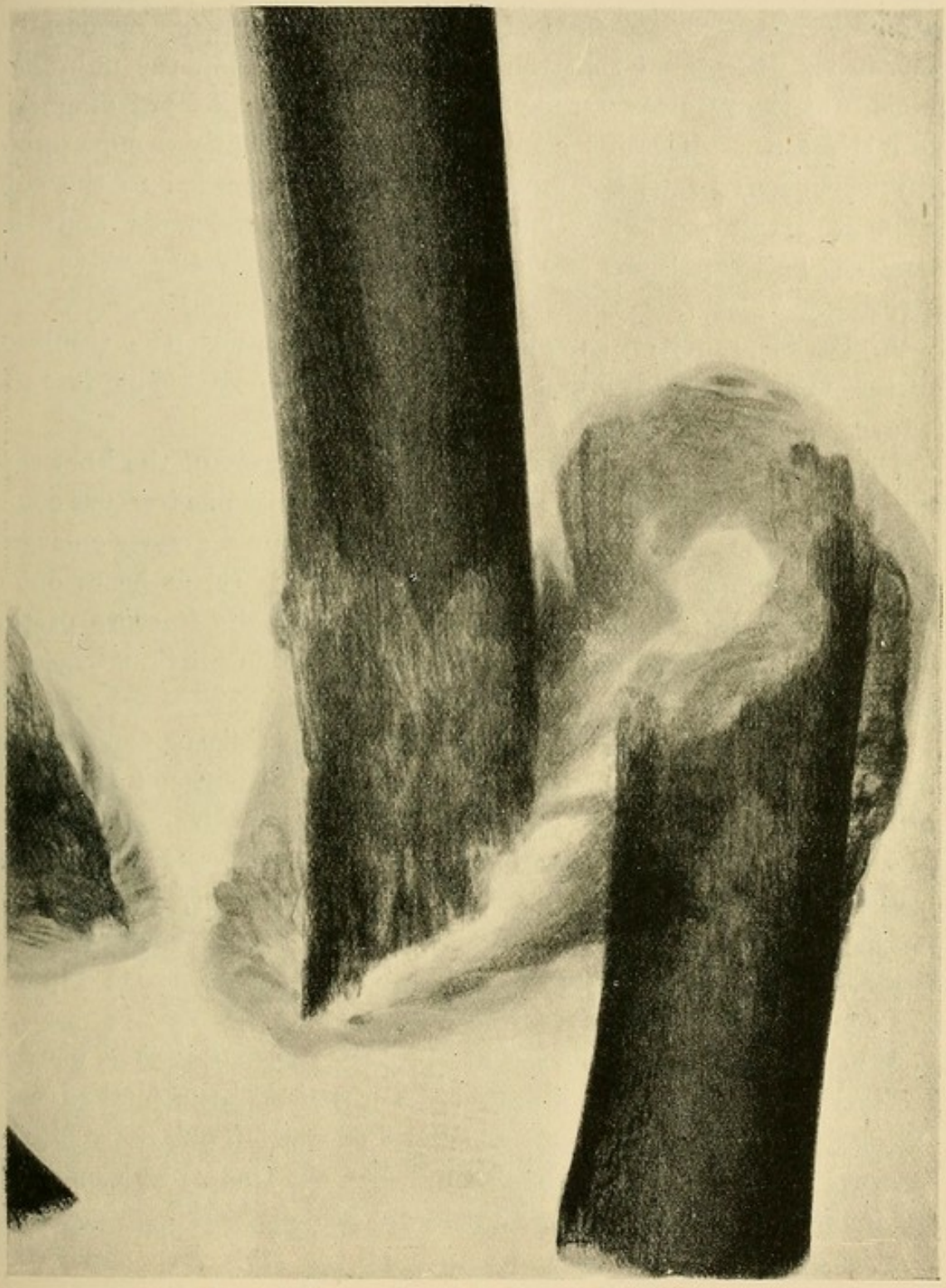


FIG. 101.—FRACTURED FEMUR: FALSE JOINT.
Mr. Robert Jones. Taken by Dr. Morgan.

had rendered complete. Wherever the truth lay in that particular instance, it is clear that the medical man first in attendance would

have been in a very different position had it been possible to secure the evidence of a Röntgen photograph. Recently at a society two photographs were exhibited of a patella, the day before and the day after its fracture. The facts of the case did not transpire generally, but it may be stated that the first picture, showing the unbroken bone, was the result of an exposure taken for purposes of diagnosis in a stiff knee. Interarticular adhesions were clearly demonstrated (by exclusion) to be the cause. Forcible flexion led to the subsequent fracture of the knee-pan. The resemblances and the contrast between these two cases are not a little suggestive and striking.

A. Barker reported a stellate fracture of patella, the result of direct violence, that might have been overlooked but for the *x*-rays.

Dr. J. N. Henry* reports a case of two fractures of the knee-cap, one following eight months after the other. Only one fracture could be felt, but the radiogram showed two fractures in a greatly enlarged knee-cap, measuring $3\frac{1}{4}$ inches in length. This result bears out a statement of Hamilton, that five months after the fracture of the knee-cap refracture is not more likely than if the previous fracture had not occurred.

In fractures of the leg, when either the tibia or the fibula is alone broken, the diagnosis, as every practical surgeon knows, is often extremely difficult. Indeed, if there be much swelling, it is in many instances impossible to determine whether the injury is a fracture or merely a sprain. Any such doubt, however, can be speedily cleared away by the rays. The most conservative of surgeons will hardly deny that the ability to settle such a point has constituted a solid advance in practice.

When both bones of the leg are broken, the diagnosis is usually so clear as to need no confirmation. Nevertheless, the method may be of use in determining whether the degree of obliquity of the fracture or the amount of displacement of the fragments would call for immediate screwing of the bones.

A so-called "rare" spiral fracture of the tibia was discovered under the rays by Dr. Taft,† and by the kindness of that gentleman is reproduced in Fig. 102. Subsequent investigations have demonstrated that these spiral fractures are really quite common, and

* *American Journal of Medical Sciences*, August, 1899, p. 183.

† *Boston Medical and Surgical Reporter*, February 25, 1897.

Dr. Joseph Griffiths,* Reader in Surgery at Cambridge, has shown, from a vast collection of pathological specimens, that spiral fracture

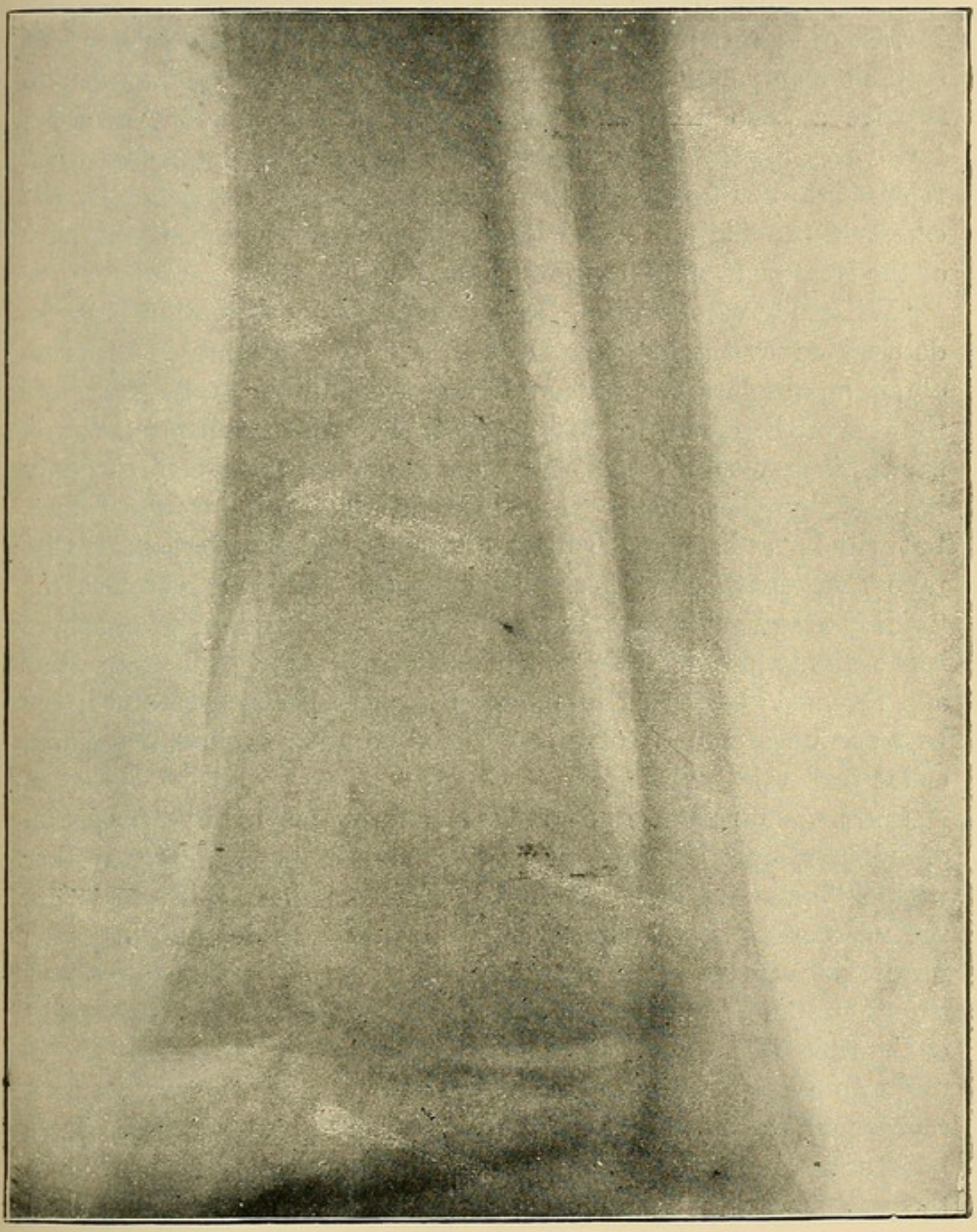


FIG. 102.—SO-CALLED 'RARE' SPIRAL FRACTURE OF TIBIA.
Dr. Taft's case. 1897.

is the most common form of fracture so far as the tibia is concerned. This view has been confirmed by numerous observations of

* *British Medical Journal*, April 21, 1900, p. 948.

different radiographers since Dr. Griffiths drew special attention to their occurrence.

With regard to the indications for operation in such fractures Mr. Golding Bird says: 'Operation is called for in cases where the suitable manipulations required by the oblique or spiral fracture fail to give a good position. The procedure need not, of necessity, involve wiring, or even screwing, for sometimes the fragments when replaced do not tend to move. This, however, is not generally the case, and the addition of a wire, which does not add to the gravity of the treatment, makes assurance doubly sure.

'What degree of "riding fragment" calls for operation must be determined by the surgeon in each case. To operate in order to obtain an absolute linear adaptation of the shin-bone that will stand the test of the radiogram is not justifiable. A slight displacement—say $\frac{1}{8}$ inch—looks large when photographed, and can certainly be felt by the finger; but it is not only of no importance, but will have disappeared by the natural modelling processes that take place in the course of a few months. Where, however, the "riding fragment" threatens to become compound, or where there is shortening, or where the foot cannot be placed in its proper line and retained there, then it is (circumstances permitting, and if the best results are to be obtained) that operation is, in my opinion, called for.'

Another unusual fracture of the tibia was reported by Mr. Hatch, of Johannesburg.* There were $1\frac{1}{2}$ inches of shortening, together with stiffness and deformity. The Röntgen method showed that the main fracture was transverse below the head of the tibia, with impaction of the lower fragment. The head of the fibula was thrust up, and carried with it the broken-off external tuberosity of the tibia.

By no available means of investigation other than the Röntgen rays could the exact nature of the two foregoing fractures have been ascertained in the living subject. There can be little doubt that, as cases accumulate, many hitherto unsuspected forms and combinations of fractures will be recorded.

The double fracture of the leg shown in Fig. 103 is from a picture kindly placed at the disposal of the writer by Dr. F. H. Low. The patient was a medical student of about twenty-two or twenty-three years of age. His leg was put up in splints in the ordinary way,

* *St. Mary's Hospital Gazette* for March, 1897.

and he was kept in bed for nine weeks. A ray photograph, taken three months after the accident, revealed the state of affairs to be seen in the picture. The lower fragments appear to have been thrust upwards between the upper, a condition which the medical attendant supposed to be due to the fact that the patient had used the limb before the bones were firmly consolidated. In the light of numerous other observations, however, it would appear that such irregular union is the rule rather than the exception. A further point of general interest is that, in spite of the apparent extent of the deformity, careful measurement showed only $\frac{1}{8}$ inch of shortening in the whole limb. No noticeable alteration was caused in the gait, probably because there was some compensatory depression of the pelvis on the injured side.

Double *Transverse fracture* of tibia and fibula is admirably illustrated in Fig. 104 from a radiogram taken by Dr. Morgan. It is of special interest because of the atrophic condition and pencilled outline of the bones below the seat of fracture.

As to fractures of the lower end of the bones of the leg, the pathology of Pott's fracture, like that of Colles's of the radius, has been to some extent rewritten in view of the fresh facts gleaned from its study by the Röntgen rays.

Special attention has been given to this point by Destot of Lyons, who has detected by the rays no less than seventeen instances of fracture of the astragalus and metatarsals.*

As a result of his radioscopic investigations of fractures of the astragalus, Destot has recognised two chief varieties—(1) *Fracture with displacement:* (*a*) When the displacement is forwards, the fragment projects under the skin, either in the middle line or on one side. (*b*) When it is backwards, the body of the bone bulges out more or less beneath the Achilles tendon. There is also an intermediate type in which the tibio-peroneal ligament accompanies the posterior fragment, and the foot is slightly dislocated forwards. (2) *Fracture without displacement:* (*a*) Complicated; three varieties —calcanean, malleolar, and scaphoid. (*b*) Simple, either through the neck, the anterior or the posterior extremity.

The Röntgen photograph of dislocation of astragalus, with rotation on its transverse axis, is a good specimen of a not frequent injury, and one difficult to estimate exactly without the *x*-ray method of investigation (Fig 113).

* 'Radioscopie et Radiographie Cliniques,' Dr. Réguier. Baillière, Paris, 1899, p. 53.

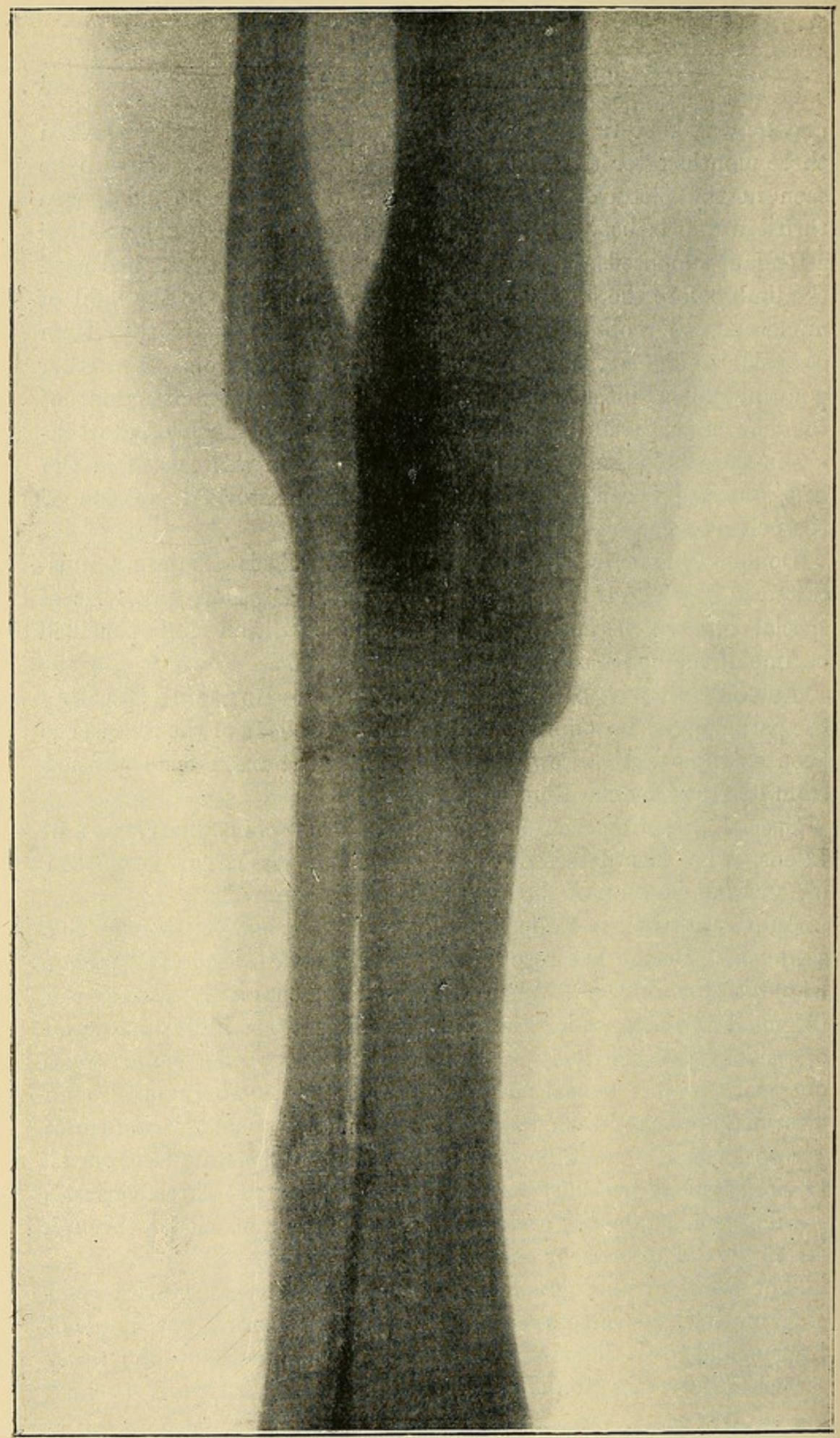


FIG. 103.—FRACTURE OF TIBIA AND FIBULA; THREE MONTHS AFTER INJURY; NO EXTERNAL DEFORMITY.

Dr. Low's case.

A helpful classification of fractures about the ankle-joint is that of Stimson, modified by Barnard by the addition of Dupuytren's fracture, as follows:

1. Eversion and abduction fractures: Pott's fracture or fracture-dislocation.
2. Inversion fractures.
3. Fracture by upward violence, driving the astragalus between the tibia and fibula: Dupuytren's fracture.

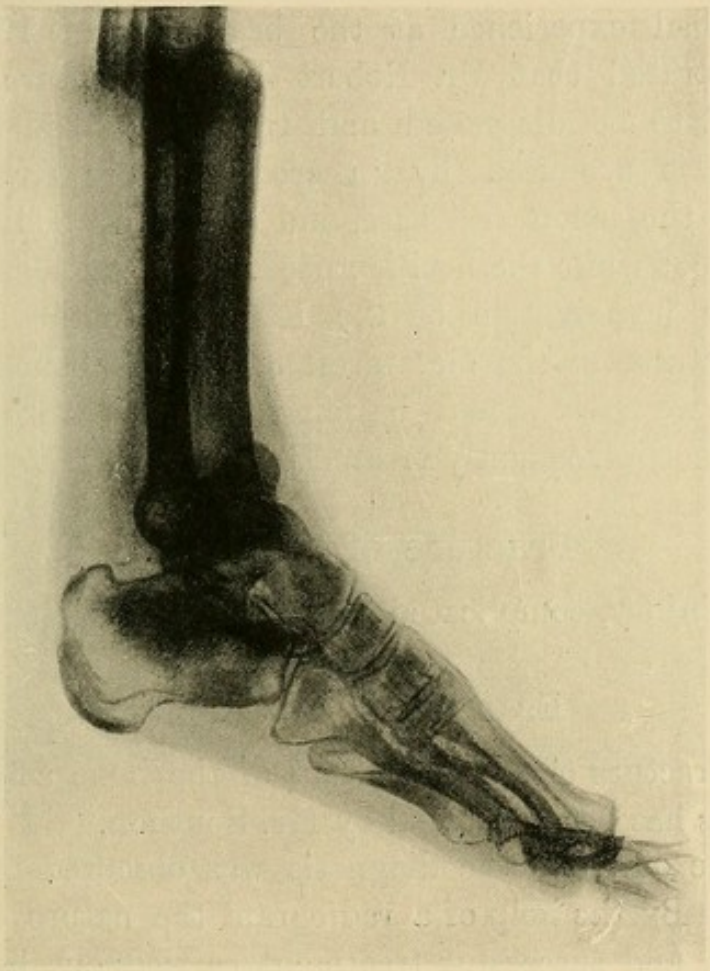


FIG. 104. — BONES OF FOOT SHOWING ATROPHY AND PENCILLED OUTLINE FOLLOWING FRACTURE OF TIBIA AND FIBULA.

Mr. Robert Jones's case. Radiographed by Dr. D. Morgan.

Pott's fracture is, of course, by far the commonest of these injuries, while Dupuytren's occurs only once in about a hundred cases of fracture round the ankle.

Fractures of the Foot.—Tarsal and metatarsal fractures are often obscure, and are no doubt at times treated as sprains. An interesting case of this kind brought under the notice of the writer was that of a young lady whose foot was injured by a fall from a

bicycle. Some six weeks later, as the foot was still painful, it was radiographed, with the result that an unsuspected metacarpal fracture was at once revealed.

It was formerly taught that fractures of metatarsals are always the result of direct violence. Mr. Robert Jones of Liverpool, however, has recorded his personal experience of fracture of the fifth metatarsal bone, caused by *indirect* violence—viz., by dancing and treading too vigorously on the outer side of his foot. He has radiographed a large number of similar accidents since his painful personal experience at the beginning of 1902. *X*-rays have demonstrated that Mr. Robert Jones's fracture is common in what used to be diagnosed and treated as 'bad sprains,' and this fracture is produced by 'a cross-breaking strain, directed anteriorly to the metatarsal base, and caused by body pressure on an inverted foot while the heel is raised.'

Before the introduction of the Röntgen methods little was heard of fractures of the metatarsal and tarsal bones. These injuries, which we now know to be fairly common, were regarded as sprains, and not infrequently treated by massage.

Fracture of Scaphoid.

This rare injury, complicated with dislocation, is well illustrated in Fig. 105.

Fracture of Os Calcis.

A case of fracture of the upper part of the bone attached to the tendo Achillis has been reported by Mr. Southon.* No crepitation could be made out, and the diagnosis was obscured by effusion of much blood. By the help of a radiogram the nature of the injury was revealed, and successful treatment carried out by wiring the fragments and fixing the foot so as to relax the calf muscles.

Mr. Albert Carless, M.S., has published an account of fractures of the os calcis, illustrated by Mr. Stephen Mayou, F.R.C..S He points out that the fractures formerly described were separation of the epiphysis and crushing from direct violence. Both injuries are rare, but there is a common form due to falling upon the feet from a height. The line of fracture may take various directions, and the bones may be comminuted or impacted. One of his illustrations, an old-standing traumatic flat-foot, due to an

* *Medical Chronicle*, June, 1900.

injury of this kind, is worth bearing in mind when dealing with flat-foot, especially as the os calcis is often fractured in both feet.

Fracture of Metatarsal.

H. L. Barnard relates a case in which all the metatarsals of a labourer's foot were broken by a fall upon the foot from a scaffold. The base of the first metatarsal bone was impacted. For a description of this interesting case with an accompanying radiogram, see the *Practitioner*, October, 1901, p. 425.

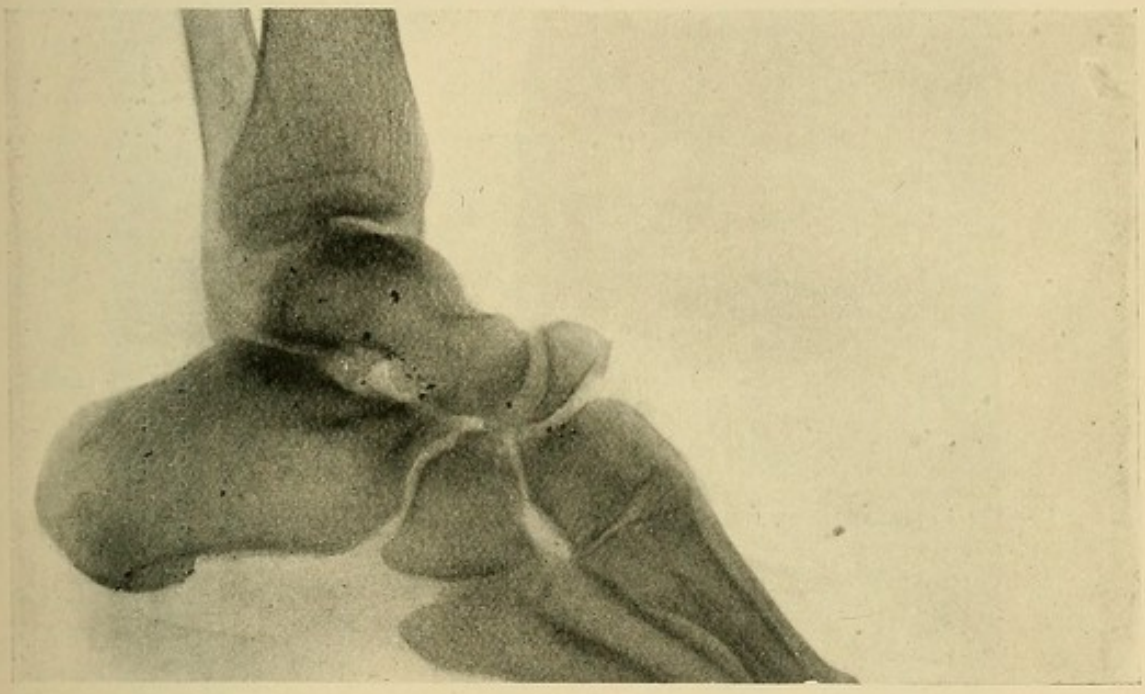


FIG. 105.—FRACTURE AND DISPLACEMENT OF SCAPHOID IN ADULT.
Mr. Robert Jones's case. Dr. Morgan.

Fractures about the Head.

Fractured skull may be readily shown by the *x*-rays when situated upon the face or the cranium—that is to say, anywhere except at the base of the skull. In the lower jaw fractures can be readily demonstrated by using the method described for taking teeth (q.v.). In all doubtful or obscure cases the surgeon will do well to appeal to this method.

Fractures of the vertebræ, from the nature of the case, usually present little difficulty in the way of diagnosis. There are, however, instances on record of unsuspected partial fractures of the vertebræ which have been rendered complete by some move-

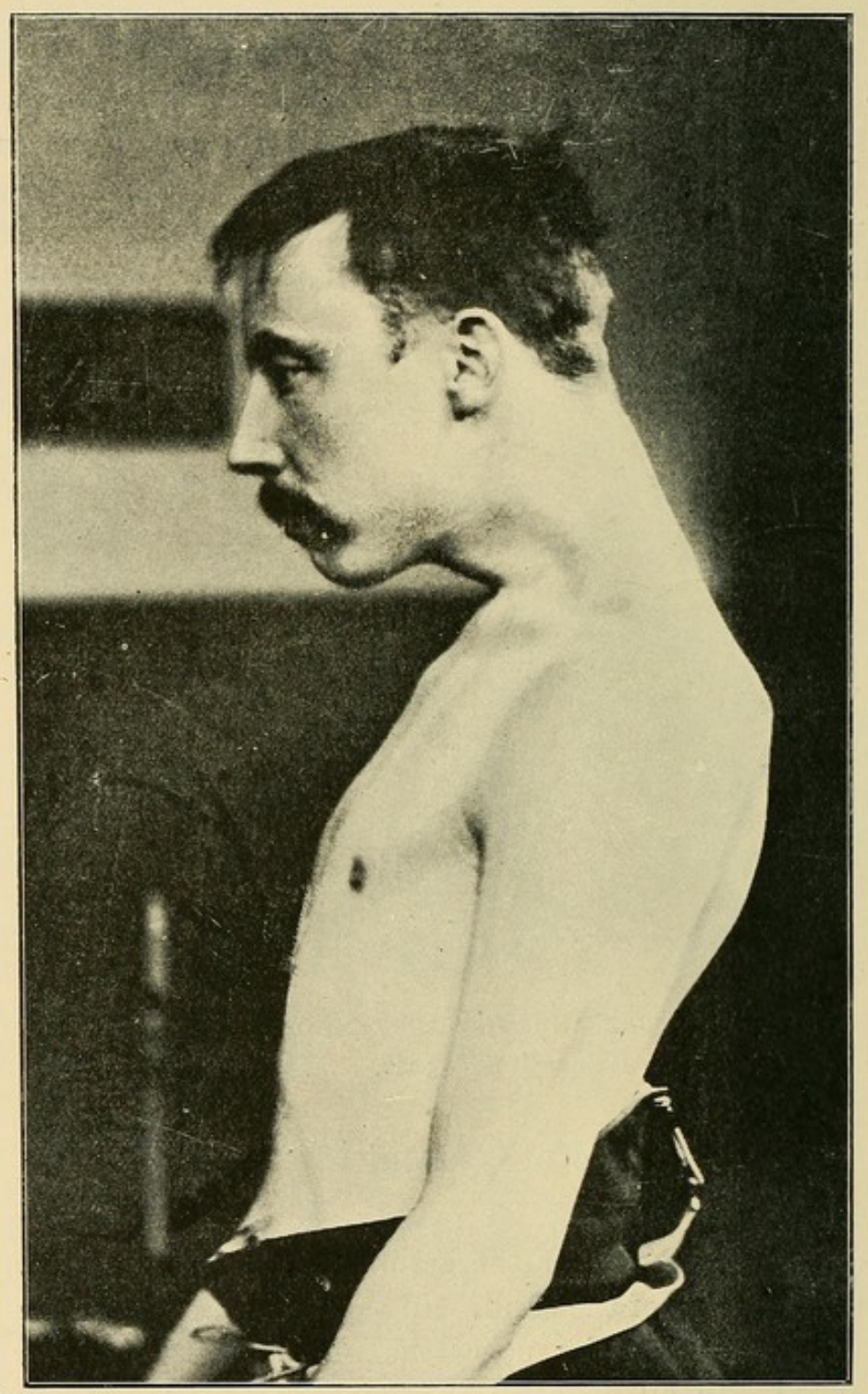


FIG. 106.—FRACTURE-DISLOCATION OF CERVICAL SPINE.
From the *Sheffield Medical Journal.*

ment, voluntary or involuntary, on the part of the patient. Thus, a patient has been known suddenly to break off a partially fractured odontoid process of the axis by nodding his head. Another, again, suffering from obscure cervical injury, has been suspected of malingering, and roughly shaken up, with fatal results. In doubtful injuries of the neck and spine, therefore, it would be advisable, wherever possible, to obtain an *x*-ray record. In the neck this is comparatively easy, and at the present time equally good results can be obtained lower down the spinal column. Lastly, if fractures of the spine be exactly located by the rays, the feasibility of such surgical methods as 'wiring' might be considered by the surgeon.

An excellent illustrative case of dislocation and probable fracture of cervical vertebræ has been published by Mr. R. J. Pye-Smith, of Sheffield.* The diagnosis rested on the nature of the accident, the region of pain, the posture of the neck and limitation of its movements, and the evidence afforded by the Röntgen rays.

The following extracts will explain the chief points of this probably unique case :

P. H., a mechanic, aged twenty-six, admitted to hospital February, 1897, complaining of pains in shoulders and upper thorax. On June 20, 1896, he fell from a raised path on to the road 6 feet below, alighting on the right side of the head. He was unconscious for half an hour, and was kept in bed for two days. His neck was stiff, and he could not raise his head properly, but in ten days he returned to his work, which involved bending his head over a machine. Six months later pain began in the chest down to the nipples, in both shoulders, and on the inner aspect of both arms.

The head was inclined forwards and slightly to the left, and could not be fully extended either by voluntary or assisted efforts. Nodding movements almost normal. Lateral rotation of head slightly limited to right, more so to left, and accompanied by a soft, grating sensation, as if tendinous fibres were slipping over bony prominences. Lateral flexion of neck markedly diminished, especially to the right. No marked lateral deformity on either side. The spinous processes of the vertebræ above the fourth could not be felt, and seemed to be displaced forwards, the fourth being very prominent. No definite projection, however, of the body of the fourth could be felt in the pharynx. The chest and abdomen moved well in respiration, and neither loss of muscular power nor of sensation was anywhere detected. The pain complained of lay chiefly in the distribution of the descending superficial branches of the cervical plexus of nerves. The Röntgen photograph taken from the side showed the body of the third cervical vertebra to be a considerable fraction of an inch in advance of that of the fourth, whilst the postero-lateral view taken from the left side showed considerable separation of the transverse processes of those two vertebræ.

REMARKS.—'The rarity of the long survival of a case of fracture-dislocation

* *The Sheffield Quarterly Medical Journal*, October, 1897, p. 30.

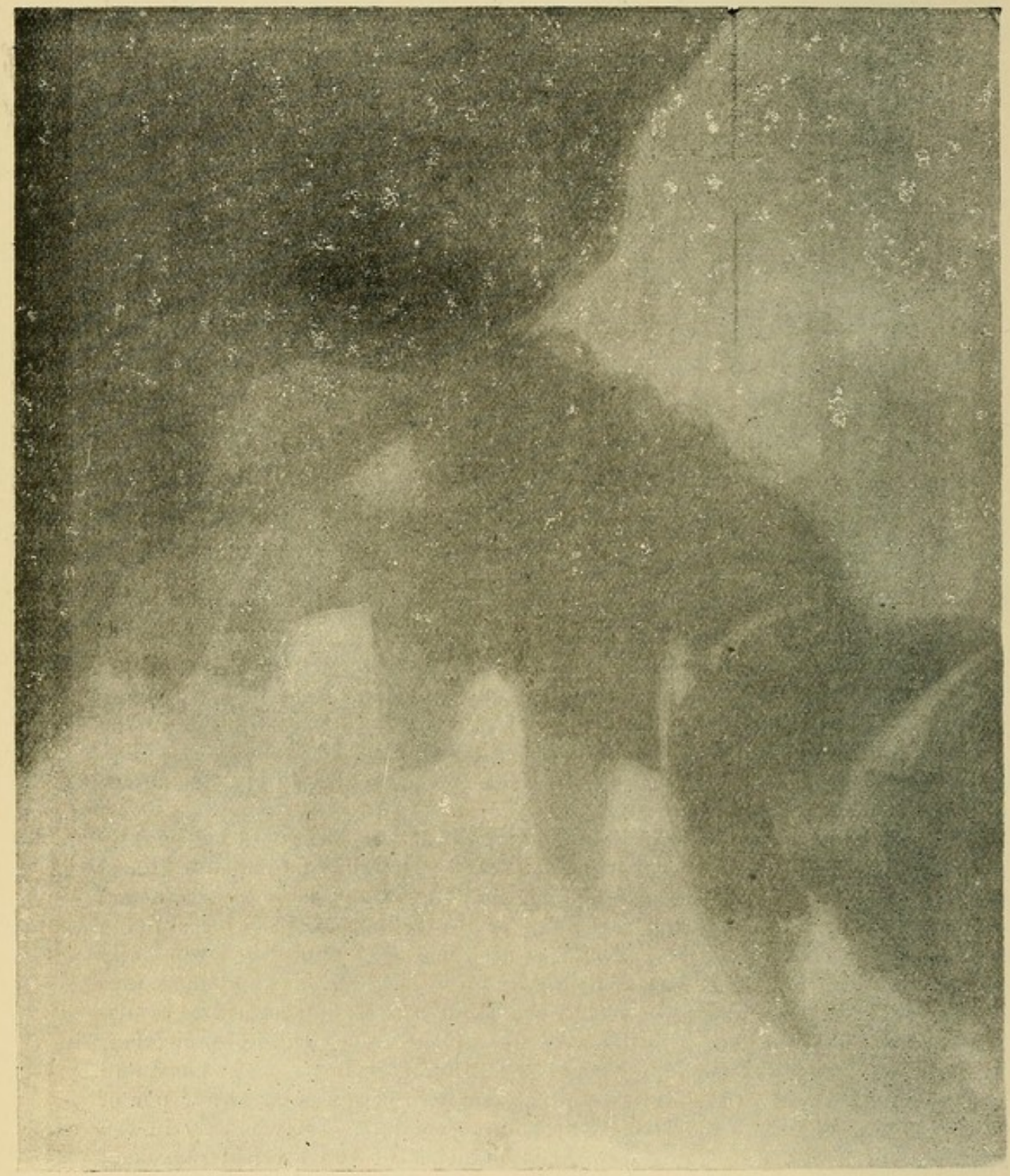


FIG. 107.—FRACTURE-DISLOCATION OF CERVICAL SPINE. From side. Mr. Pye-Smith's case.

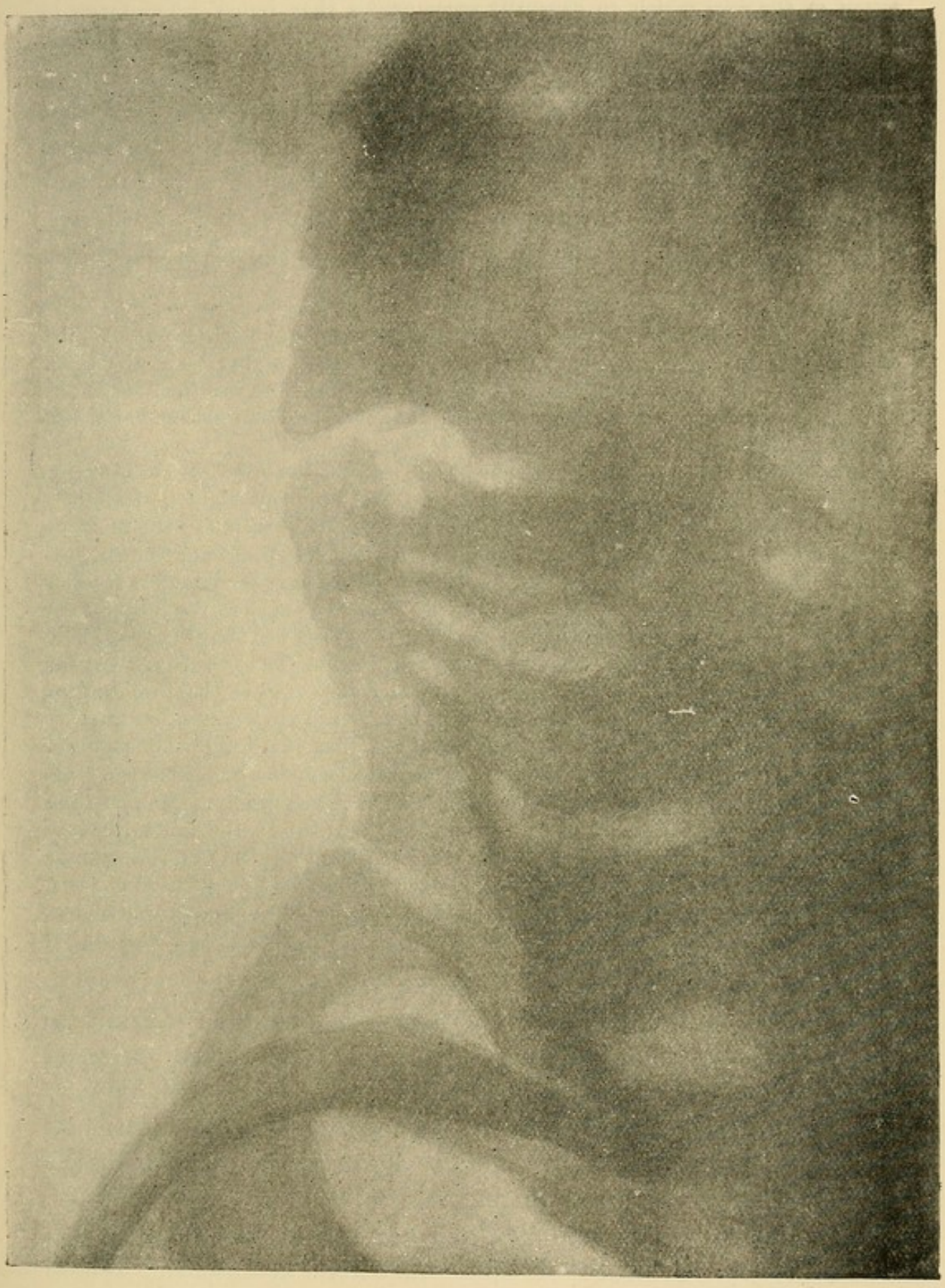


FIG. 108.—FRACTURE-DISLOCATION OF THE NECK. Antero-posterior view. Mr. Pye-Smith's case.

of the spine in the cervical region is well known, and depends, of course, on the lesion of the cord which so generally accompanies that injury. The rarity of such an injury to bone and ligament without involvement of the cord is perhaps equally great.'

A case of fracture-dislocation of the cervical vertebræ has been published by Ernest Ringrose, M.R.C.S.* It shows that extensive injury of the lower cervical vertebræ may produce only few and transient symptoms. Moreover, the case shows that it was excusable not to diagnose an injury of that kind in the pre-Röntgen-ray days.

A boy, aged fourteen, was admitted to hospital on June 28, 1894. Whilst diving into the river he collided with a man who was swimming by at the time. He was partially stunned, but managed to reach the bank, and was then taken out of the water and carried to the hospital. He never lost consciousness, but felt 'queer in his head.'

On admission he complained of headache and pain at the lower part of his neck. There was no loss of power or of sensation. The neck was rigid and slightly tender. There was no bruising, and no deformity was to be seen. In the morning he was unable to move his head, except with a limited side-to-side movement, extension being much more restricted than flexion. There were considerable rigidity of the neck muscles and some tenderness. He refused to stay in the hospital for more than three days, and returned home. The diagnosis was slight cerebral concussion and strain of the muscles and tissues of the neck. The author saw the lad several times afterwards at his home, and found that he was in the habit of holding his head with his right hand under the right side of the lower jaw when walking about. He continued to hold his head steady in that manner for six months. Recently he joined the militia, having been passed as sound by the surgeon. He appeared to be well set up, but he carried his head rather stiffly. He was then skiagraphed. The screen showed a forward displacement in the lower cervical region, the centre of the body of the fifth cervical vertebra resting on the anterior superior edge of the body of the sixth. The bodies of the fifth and sixth vertebræ appeared small and wedge-shaped. The body of the fourth was almost directly anterior to the fifth. The sixth and seventh cervical and first dorsal vertebræ were pushed backwards.

Fractures of the ribs, which are now and then difficult to detect, may be diagnosed by radiography. In some instances —as, for example, in lunatic asylums—the proof of such injuries may have a medico-legal interest. Indeed, it may be mentioned in passing that the rays are likely to be of special service to the surgeon when called upon to diagnose injuries of lunatics, mutes, infants, and other folk who are from any reason unable to furnish sound personal evidence of their subjective symptoms. Where death has taken place, a tedious dissection may perhaps be avoided by a Röntgen photograph.

* *Lancet*, October 15, 1904.

There are special difficulties in the way of securing a proper record of rib injuries. For instance, the respiratory movements of the chest wall confuse the focus-tube shadow more or less. It has been suggested that the ribs may be fixed by a dressing translucent to the rays, such as silicate of soda. When the fracture is at or within the neck, the movements are sufficiently restrained simply by lying on the back. In that way Mr. C. G. Burton and Dr. Walsh secured an excellent picture of seven broken ribs at the North-Eastern Children's Hospital, London. The patient was a child who had been run over by a vehicle ; the fracture had united when the exposure was made several weeks after the accident. The photograph was darker on the affected side, owing to the absorption by the skin of a certain amount of lead from the plaster which had been applied to fix that half of the chest, and also to traumatic pleurisy.

It is difficult in adults to obtain any record of the ribs over the region of the liver. Dr. Walsh failed to do so in a medico-legal case where fracture of the lower ribs was alleged to have taken place in the nipple line as a result of direct violence (fall on kerb-stone). The patient in that case was an elderly asthmatic man of great girth. In another instance, however, he secured a clear record of ribs over the liver in a middle-aged man of average size, by causing the patient to fix the part to be taken by leaning firmly against the sensitive plate. In young adults and children the ribs can often be beautifully shown through the liver by taking them lying face downwards.

There seems to be no particular reason why lateral fractures should not be photographed if the chest be fixed in some way and the rays directed transversely through the thorax from the sound side. Many of the above difficulties can be obviated by making patients hold their breath during the application of the *x*-rays and turning off the rays at a given signal, and reapplying the rays when the chest has resumed the position it was in during the original exposure.

Concluding.

This section may be finished by quoting some important practical conclusions arrived at by two surgeons, one in Germany and the other in America. For some months both made a routine practice

of examining with the Röntgen rays every fracture brought under their notice.

The chief point insisted upon by Dr. Richardson of Boston is that both in recent and in united stages malposition of broken ends is common, although not revealed by any previously known method of examination. He mentions a number of cases where the position was absolutely perfect so far as could be ascertained by ordinary means, but in which, nevertheless, a Röntgen-ray photograph showed considerable displacement.

Oberst of Halle finds that without the aid of anæsthetics and without handling the parts he can make an exact diagnosis as to the position, the nature, and the direction of fractures. He thus avoids the danger of laceration of vessels and of other structures that attends manipulation of the fragments. Ether he now reserves for painful reductions. He also makes a practice of taking a radiograph at the end of treatment. His main conclusions are as follows :

1. The ideal or perfect union is rare.

2. In all oblique fractures there is more or less overriding of the broken ends.

3. In bones that are deeply seated considerable deformities may escape notice.

4. In cases followed by long-continued functional disturbances, the Röntgen rays invariably showed overriding of fragments to a greater or less extent, when manual examination revealed no deformity.

DISLOCATIONS.

In this class of injury the surgeon will usually arrive at a fairly accurate diagnosis by ordinary methods.

A dislocation may be examined with advantage when the parts are too swollen and painful to admit of manipultaion. When complicated with fracture, the value of the new method can hardly be overestimated for the ease with which a difficult diagnosis may be reduced to a certainty. To take a concrete instance, let us suppose a dislocation of the elbow to be examined by the *x*-rays, which may demonstrate one or more of the following fractures as a complication—(1) of the coronoid, (2) of the olecranon, (3) of the neck of the radius, (4) of lower end of humerus, (5) of condyles of humerus, (6) through epiphysis of humerus. The importance of

trustworthy evidence on any of these points must be clear, when one considers to what an extent such knowledge must modify diagnosis, prognosis, and treatment. The illustration of backward

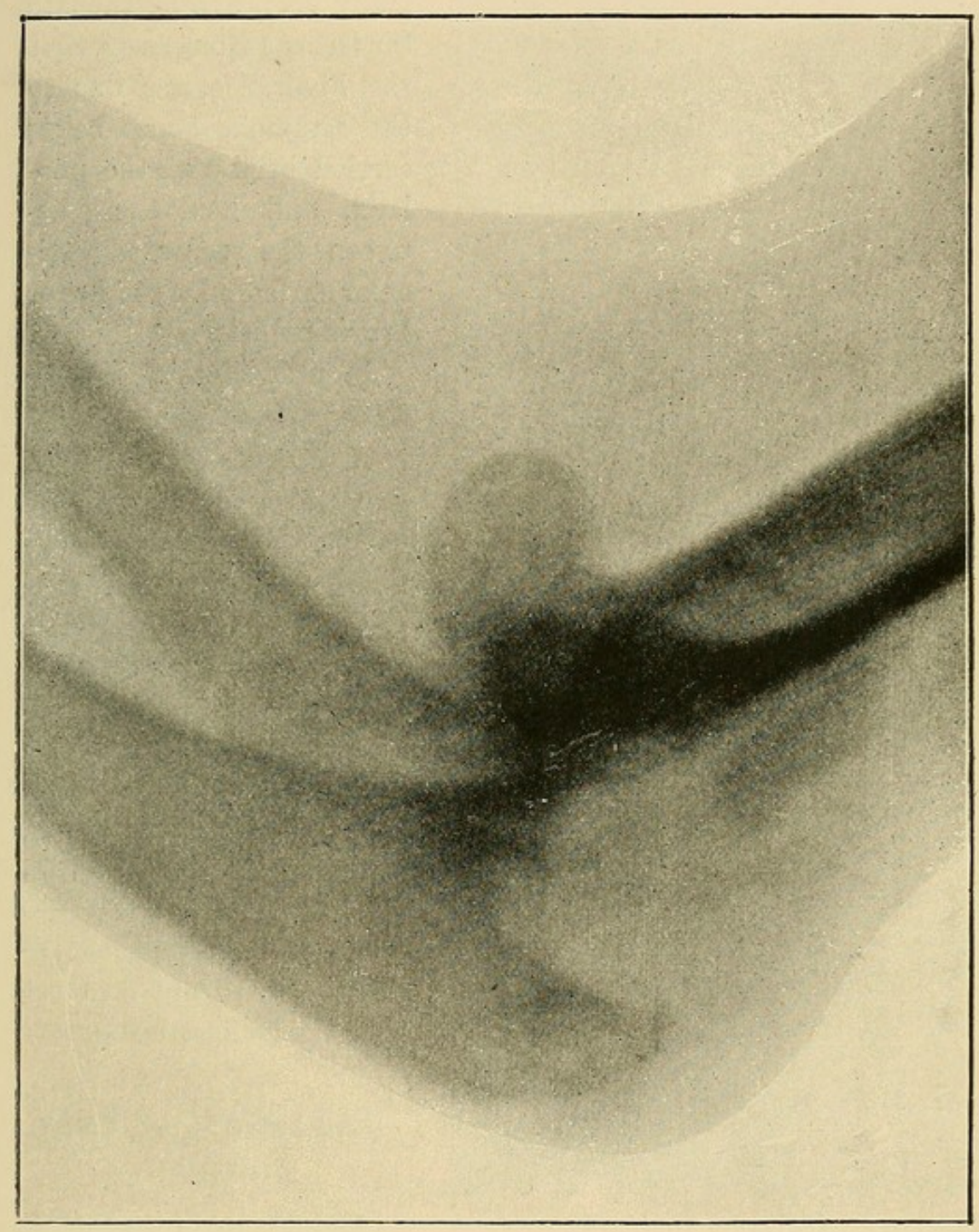


FIG. 109.—BACKWARD DISLOCATION OF BONES OF FOREARM IN A CHILD.

elbow dislocation of both bones of the forearm in a child shown in Fig. 109, is from an early ray photograph by Davidson.

The backward dislocation of the first phalanx of the thumb upon the metacarpal has always been a matter of surgical interest,

chiefly because of the difficulty often experienced in replacing the bones. It is interesting to note that the rays have confirmed the anatomical theory advanced many years ago by the late Sir George Humphrey, that the hindrance was due to the sesamoid bones being carried back with the phalanx, and held there between the separated articular surfaces by the flexor brevis pollicis.

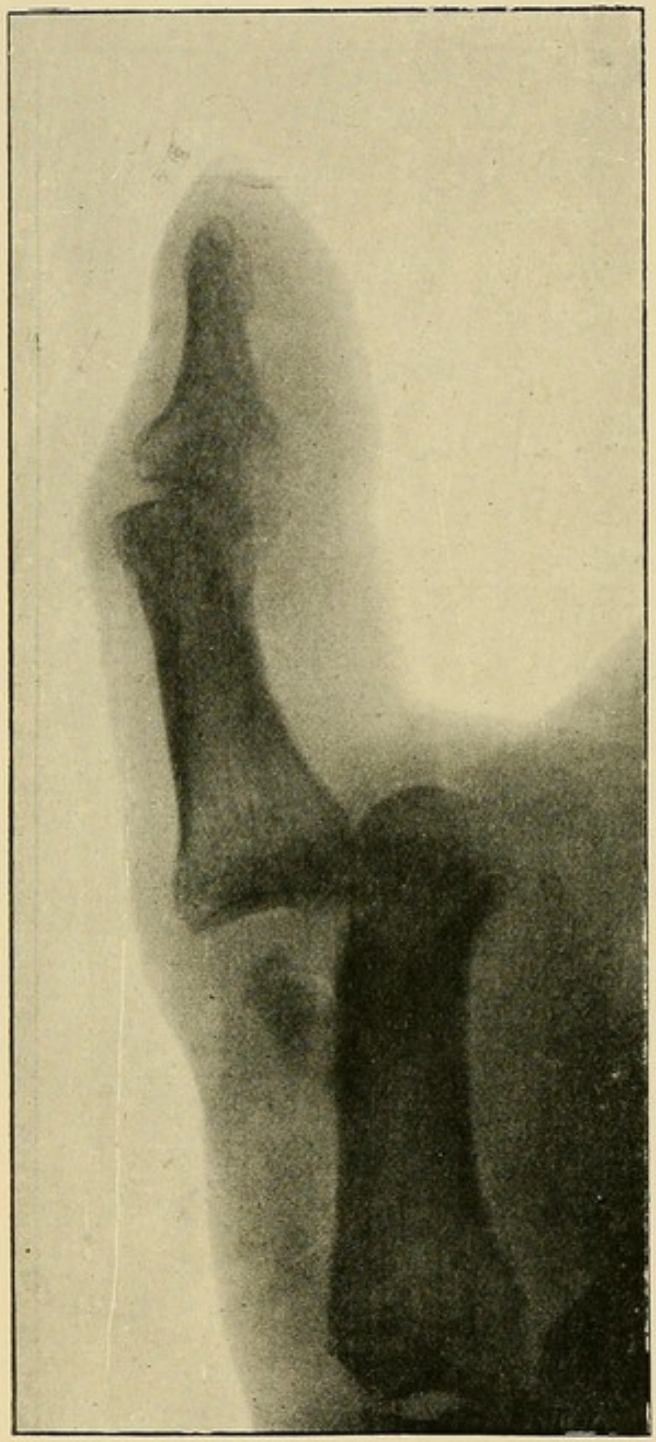


FIG. 110.—BACKWARD DISLOCATION (OLD) OF METACARPO-PHALANGEAL JOINT OF THUMB. Position of sesamoids behind and below head of metacarpal well shown. Lynn Thomas.

In old-standing dislocations the new photography is of service. For instance, it enables the surgeon to ascertain the precise condition of affairs at the seat of injury, so that his treatment shall be founded upon exact data. Thus, if the rays showed a fresh articulation to have been formed in an old-standing dislocation of the shoulder, the surgeon would not make any attempt at reduction, except under most exceptional circumstances.

Dislocations of Knee and Foot.

An instance of that somewhat rare injury—dislocation of the knee—was reported by Mr. T. P. Carlion, from Woolwich Arsenal.

The injury was caused by a sack striking the inner side of the eg while the thigh was fixed from the outside.

Mr R. J. Pye-Smith,* of Sheffield, has published radiograms showing the foot dislocated backwards, and also showing the result of operation effecting the reduction after removal of a large portion of the astragalus.

The same surgeon has published a case of fracture of the shaft of the ulna, with dislocation of the head of the radius. The injury had taken place some little time previously, and the radiogram revealed a remarkable amount of new bone surrounding the dislocated head of the radius. Reduction being found impossible without operation, the head of the radius was excised together

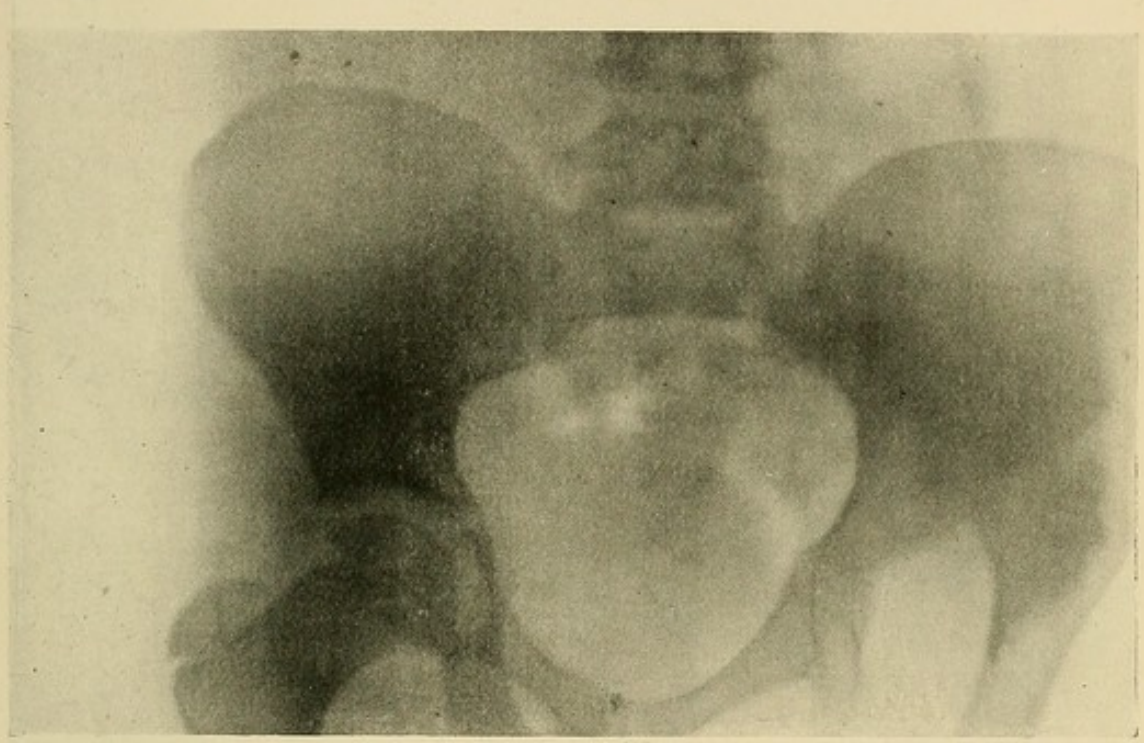


FIG. 111.—CONGENITAL DISLOCATION OF RIGHT HIP IN A CHILD AGED 8¾ YEARS, BEFORE OPERATION.

Mr. Robert Jones's case. Dr. Morgan.

with the new bone which appeared to have been thrown out by the periosteum of the humerus.

In the same paper he reports a traumatic dislocation forwards of the head of the fibula.

Congenital dislocation of the hip can be well shown in children, and Mr. Robert Jones, of Liverpool, has exhibited an interesting series of skiagraphs showing the relative positions of the head of the femur to the acetabulum *before*, *during*, and *after* treatment by the bloodless method of Lorenz.

* *Quarterly Medical Journal*, August 1900, p. 405.

Sometimes a suspected congenital double dislocation may be really due to a rickety bending of the angles of the thigh-bones.

Dislocation of the body of the astragalus backwards is an extremely rare accident. The last edition of this book contained a radiogram taken by Mr. Lynn Thomas from a lad of seventeen, who, eight months previously, while riding on a moving trolley with his feet in front, struck the roof of an underground cutting.

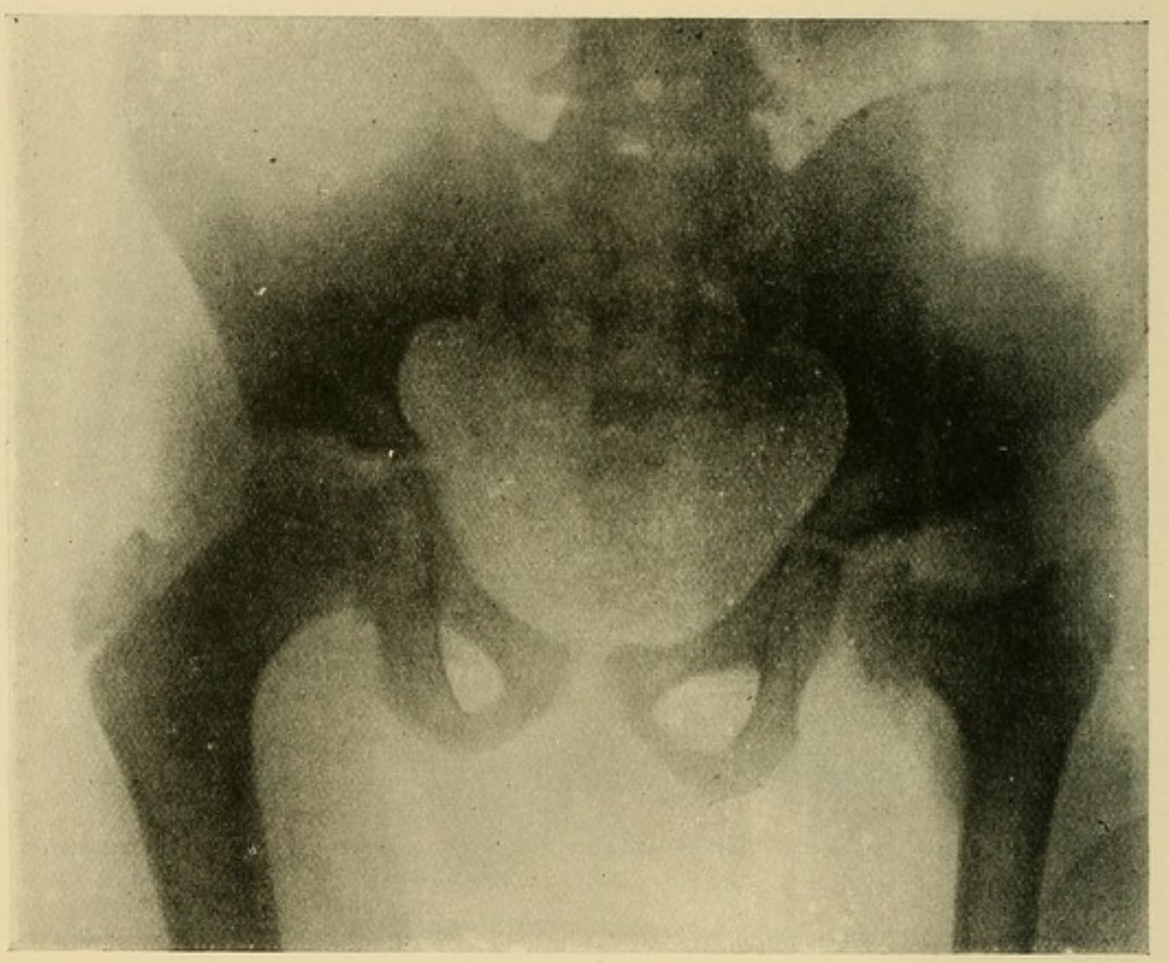


FIG. 112.—CONGENITAL DISLOCATION OF RIGHT HIP, AFTER OPERATION.
Mr. Robert Jones's case. Dr. Morgan.

There is fracture through the neck of the astragalus, while the body is displaced backwards with the trochlear surface in contact with the tendo Achillis; in other words, there is an axial rotation of 90 degrees backwards through its transverse axis, 'anticlockwise.'

There is no formation of bone in the gap between the neck and the displaced body of the astragalus, for the fibular malleolus is distinctly recognisable. The tibial malleolus is seen resting upon the two segments.

In Stimson's seven cases of this particular injury 'persistent flexion of the terminal phalanx of the great toe was present' (Keen and White's 'Surgery'). A similar condition was well shown in this instance.

A comparison of the bones and tendons of this radiogram with the illustration of a like injury in Treves's 'System of Surgery' (vol. i., p. 1025) is not a little striking.

By the kindness of Mr. Robert Jones an excellent example of this dislocation, complicated by fracture, is reproduced below.

Dislocation of Neck.

Case reported by Noble Smith* at the Windsor and District Medical Society.

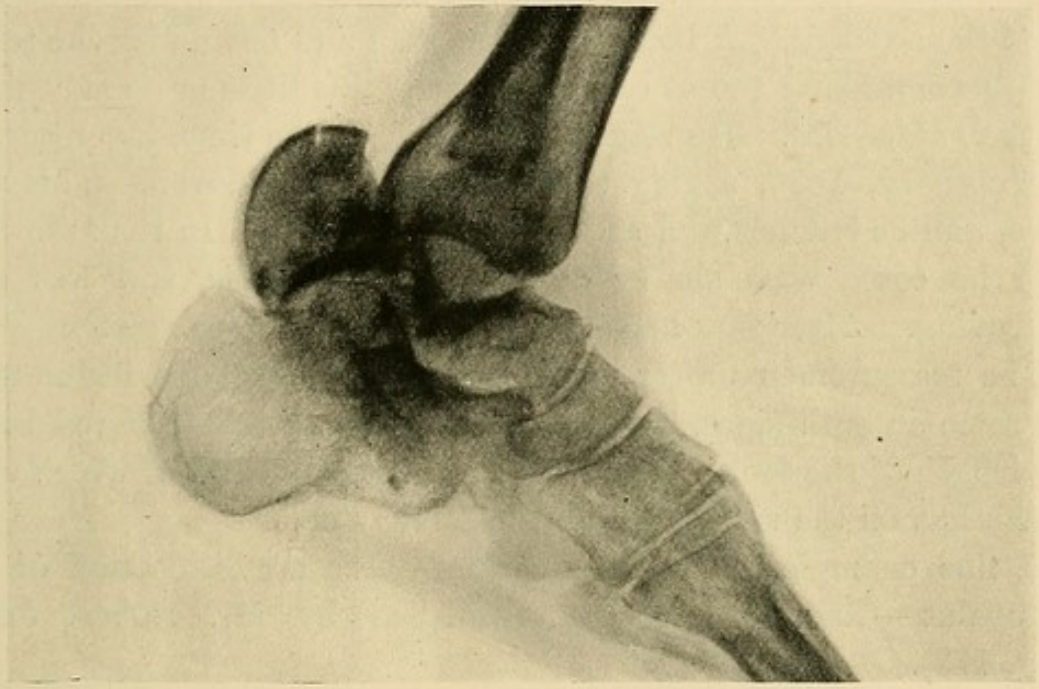


FIG. 113.—FRACTURE-DISLOCATION OF ASTRAGALUS IN ADULT.
Mr. Robert Jones's case. Dr. Morgan.

A lady sustained a fall of 80 feet down some rocks in the island of Sark. After several weeks' rest she began to get about again, and then suffered from pain and stiffness in her neck and attacks of giddiness; at the same time she would suddenly fall down. On examination, an angular deformity was detected between the fifth and sixth cervical spines, and a radiogram clearly indicated a partial displacement between those vertebræ. The dislocation was reduced under an anæsthetic.

Dislocation of Patella.

Two cases of exceedingly rare dislocation of the patella have been published by Dr. David Newman and Dr. H. Rutherford.† In the first case there was dislocation upwards by rotation of the patella on its horizontal axis, while the articular surface presented upwards.

* *Lancet*, March 3, 1900, p. 422. † *Ibid.*, June 22, 1901.

The second case is probably unique. An accompanying radiogram shows the patella 'with its articular surface turned downwards, and engaged between the femur and the tibia. The ligamentum patellæ is seen tightly stretched.'

Dislocation of Astragalus.

Mr. Robert Jackson, M.B.,* describes a case of fracture of the neck of the astragalus, with dislocation of the bone backwards, in a collier. He met with an accident in March, 1898, and was first seen by the writer in October. He had not been able to walk on the foot since the accident. A bony mass was seen and felt under the tendo Achillis and above the os calcis, and there was little or no movement of the ankle-joint. He refused operation at the time, but returned in February, 1899, asking to have the bone removed. This was done, and he left hospital at the end of a month. In the following July he could walk six or eight miles with ease, and was still improving. After that he returned to his work in the pit.

The measurements after recovery round the heel and instep were the same on both sides, the only measurements that differed being the length of the foot and the length of the legs, both of which were $\frac{3}{4}$ inch less on the right than on the sound side.

A fine example of this rare injury—fracture-dislocation of the astragalus — has been kindly furnished by Mr. Robert Jones (Fig. 113).

Dislocation of Metatarsus.

A good illustration of dislocation of the metatarsus has been published by L. H. Harris,† of Sydney.

Congenital dislocation of the shoulder is a rare condition. It has been carefully described and discussed by A. G. Cumston, M.D.‡ Many cases of traumatic dislocation during delivery and of infantile paralysis have been confused with the pure congenital condition. Cumston regards muscular soundness and electrical excitability as an essential test.

'A congenital dislocation,' he writes, 'is noticed immediately after birth, and there is a complete absence of fever. All the muscles have their voluntary contractility, while their atrophy

* *Quarterly Medical Journal*, February, 1900, p. 194.
† *Archives of the Roentgen Ray*, January, 1901.
‡ *American Journal of the Medical Sciences*, June, 1903, p. 967.

is usually due to the long inactivity to which they are subjected. Of course certain movements are rendered difficult on account of the mechanical obstacle formed by the dislocated head of the humerus, but when reduction has been performed, the functional impediment seems to disappear.'

(*c*) INJURIES TO EPIPHYSES.

The importance of injuries to the epiphyses is now recognised by surgeons, and existing knowledge on the subject has been brought together in an exhaustive monograph by Mr. Poland.*

The damage may occur in intra-uterine life, during birth, or in childhood—most often, perhaps, between the years of eleven and eighteen, up to the union of the last epiphysis, usually at twenty-three, although that may be delayed in some cases until thirty years or more. The Röntgen ray worker will be guided in the reading of results by the following table:†

THE TIMES OF THE UNION OF THE EPIPHYSES TO THE DIAPHYSES OF THE LONG BONES.

At the 16th year	The upper epiphysis of the radius.
Between the 16th and 17th years ..	The olecranon epiphysis of the ulna.
At the 17th year	The lower epiphysis of the humerus.
At the 18th year	The internal epicondyle of the humerus.
Between the 17th and 20th years ..	The epiphyses of phalanges of toes.
Between the 18th and 20th years ..	The epiphyses of phalanges of fingers and lower epiphysis of ulna.
About the 20th year	The metacarpal epiphyses.
Between the 18th and 22nd years ..	The upper epiphysis of the humerus.
Between the 19th and 23rd years ..	The lower epiphysis of the radius.
Between the 22nd and 25th years ..	The epiphysis of the clavicle.
At the 18th year	The lesser trochanter.
Between the 18th and 19th years ..	The great trochanter.
Between the 19th and 20th years ..	The metatarsal epiphyses.
At the 19th year	The epiphyseal head of the femur.
Between the 18th and 19th years ..	The lower epiphysis of the tibia.
Between the 19th and 21st years ..	The lower epiphysis of the fibula.
Between the 20th and 22nd years ..	The upper epiphysis of the fibula.
Between the 21st and 22nd years ..	The upper epiphysis of the tibia.
Between the 20th and 23rd years ..	The lower epiphysis of the femur.

Separation of epiphyses is much more common in the male sex, as shown by Poland in the three most frequent situations—namely:

Lower Epiphysis of Femur.—Out of 114 cases, the sex is stated in 96—83 males and 13 females; all the latter below fourteen years of age.

* 'Traumatic Separation of the Epiphyses,' by John Poland, F.R.C.S., London: Smith, Elder and Co., 1898.

† *Ibid.*, p. 47.

Lower Epiphysis of Radius.—Out of 112, the sex is given in 89 as 79 in males, and 10 in females; the whole of the latter being at or below fourteen years of age.

Upper Epiphysis of Humerus.—Out of 119, the sex is given in 104. Of these, 85 were males and 19 females (16 being at thirteen years and below, 3 above).

The practical worker will find the following tables from the same book of constant value for reference. The statistics are compiled from Poland's own cases of separations of epiphyses.*

UPPER EXTREMITY.

Clavicle	5
Humerus, upper epiphysis	120
,, lower end (before puberty)	75
,, lower epiphysis at and after puberty ...	6
,, internal epicondyle	61
,, external epicondyle	9
Radius, upper epiphysis	7
,, lower epiphysis	112
Ulna, upper epiphysis	9
,, lower epiphysis	11
Phalanges of fingers	3
Metacarpus	8
Total	426

LOWER EXTREMITY.

Femur, epiphysis of head	35
,, great trochanter	14
,, lesser trochanter	1
,, lower epiphysis	125
Tibia, upper epiphysis	24
,, epiphysis of tubercle	10
,, lower epiphysis	46
Fibula, upper epiphysis	3
,, lower epiphysis	5
Phalanges of toes	2
Metatarsus	2
Total	267

* *Op. cit.*, p. 56.

DIAGRAMS OF THE COMMON FORMS OF EPIPHYSEAL SEPARATION.

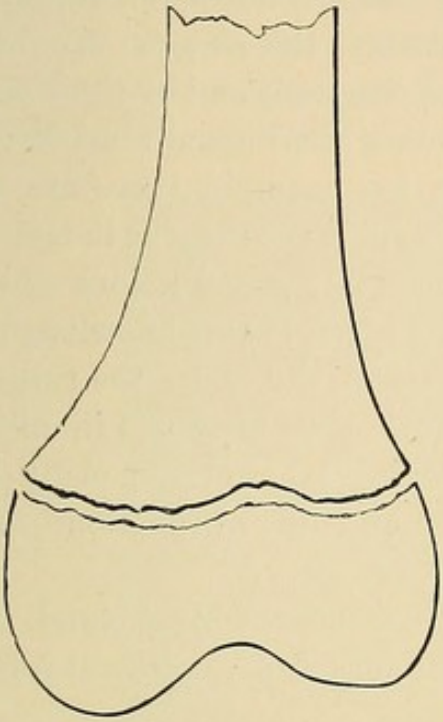


FIG. 114.—PURE AND COMPLETE SEPARATION.

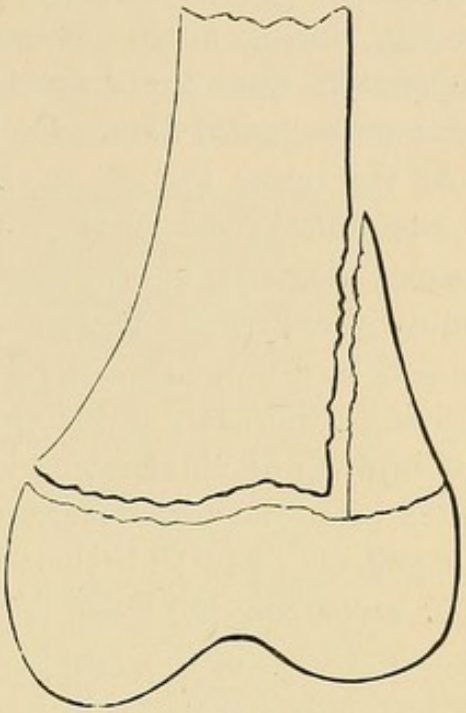


FIG. 115.—PARTIAL SEPARATION, WITH FRACTURE OF THE DIAPHYSIS.

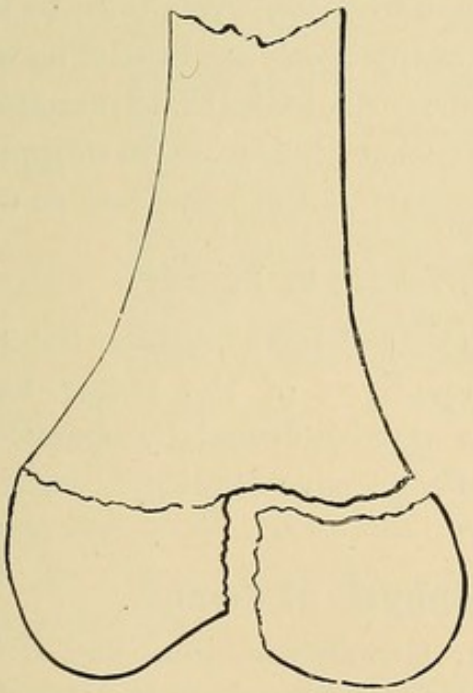


FIG. 116.—PARTIAL SEPARATION, WITH FRACTURE OF THE EPIPHYSIS.

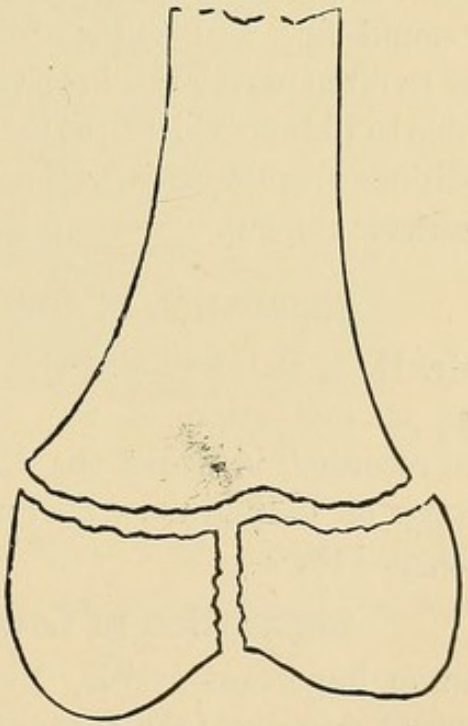


FIG. 117.—COMPLETE SEPARATION, WITH FRACTURE OF THE EPIPHYSIS.

From Poland's 'Traumatic Separation of the Epiphyses,' 1898.

The importance of an exact diagnosis in this class of injuries is clear, as severe deformities often result from them. A certain number of so-called congenital deformities are no doubt caused in this way during birth. Hitherto, however, the surgeon has been hampered by the want of exact means of diagnosis and by the lack of precise pathological data. On these points Mr. Poland remarks:

'At the lower end of the humerus, for example, there are but few anatomical specimens in museums to guide the surgeon in making an exact diagnosis of the numerous and complicated lesions which, from daily experience must exist during life. If this knowledge be obtained by Röntgen's method, it will materially assist the surgeon in giving a decision as to immediate operative measures in elbow-joint injuries of children, and in removing some of the many instances of subsequent severe deformity and loss of function of the joint and limb now so little creditable to surgery.'*

The accompanying illustrations, by permission of Mr. Poland, will give some idea of the way in which the forms of epiphyseal injury may be multiplied (Figs. 114-117).

The Röntgen ray worker has now the means of ascertaining the exact condition of parts in traumatism of the epiphyses. He will in most cases want a second or control radiogram of the corresponding sound side, and will do well to make constant reference to the book so often mentioned in the course of this section. Lastly, he will be able to obtain evidence as to the occurrence of plastic inflammatory conditions in epiphysitis, together with such complications as stripping of periosteum, suppuration, necrosis, absorption of bone, and so on.

Separation of Upper Epiphysis of Femur.

Mr. H. L. Barnard, F.R.C.S.,† says that at least fourteen definite cases of separation of the upper epiphysis of the femur have been recorded, in which the diagnosis was confirmed by operation, autopsy or radiogram. He quotes 'Progressive Medicine,' vol. iv., 1900, p. 148.

Separation of Lower Epiphysis of Femur.

In an important article, Messrs. J. Hutchinson, jun., and H. L. Barnard describe four cases of this injury treated at the London Hospital, and mention sixteen others of which they have had personal knowledge. The injury is nearly always the result of forcible hyper-

* 'Traumatic Separation of the Epiphyses,' p. 97.

† *Practitioner*, October, 1901, p. 395.

extension of the knee, and if displacement occurs, it is just as constantly a forward one of the epiphysis. By means of the Röntgen rays it was shown that in the extended position of the knee, even with an anæsthetic, reduction of the fragments was very difficult, if not impossible. The further important observation was made that with full flexion reduction was always easy. When treated in that

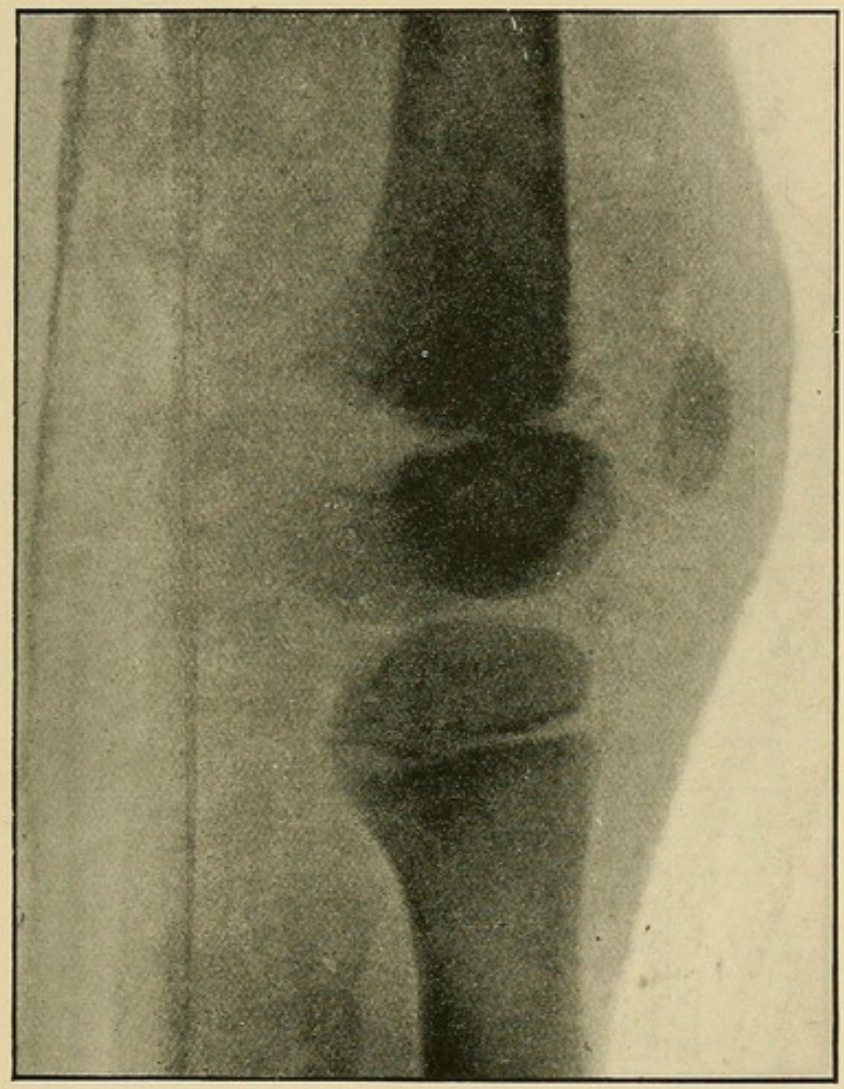


FIG. 118.—SEPARATION AND DISPLACEMENT OF LOWER FEMORAL EPIPHYSIS. Hutchinson and Barnard.

way the usual result was rapid recovery, with perfect movement of the knee, and without shortening or deformity of the leg (see Figs. 118-120).

Dislocation of the Epiphysis of a Metacarpal Bone.

Mr. E. H. Herring,* of Ballarat, found the above rare condition in a boy of ten who had injured his hand by a fall from a tree.

* *Lancet*, April 21, 1900, p. 1131.

On examination there was found on the palmar surface of the right hand over the neck of the first metacarpal bone a small, immovable, rounded, hard nodule, of about the size of a pea. Several medical men diagnosed the case as one of exostosis. Treatment failed to keep the nodule in place, and finally it was excised.

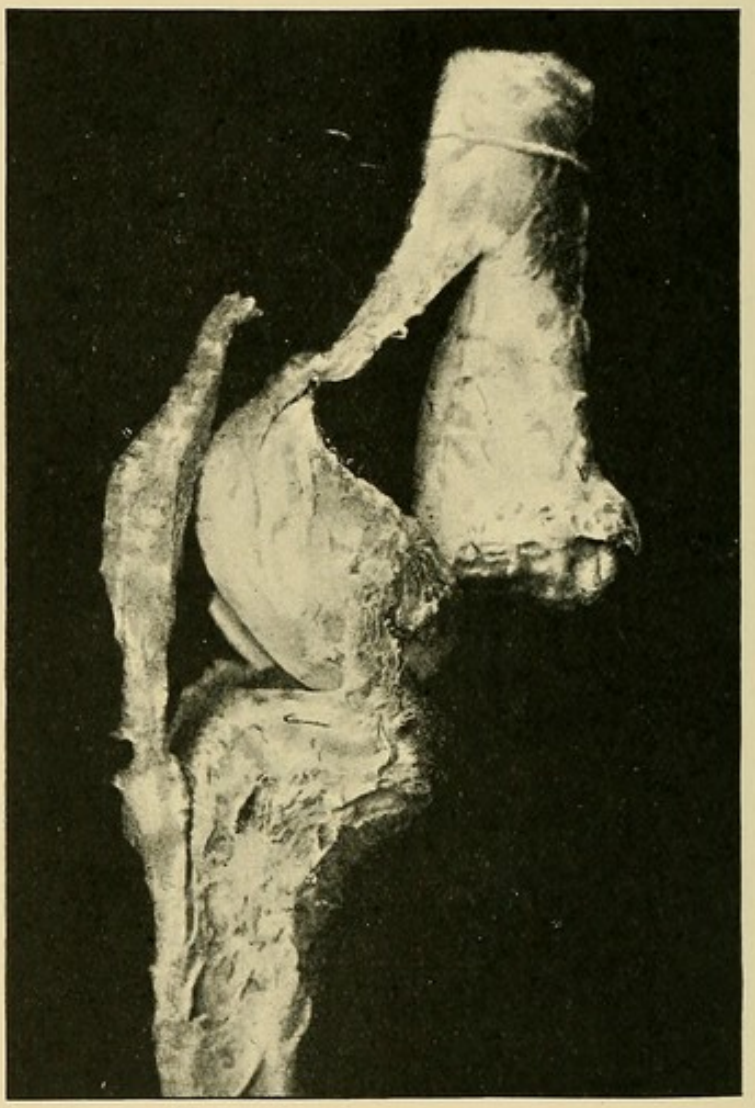


FIG. 119.—DISSECTION OF DISLOCATED FEMORAL EPIPHYSIS.
(*Medical Review.*)

Separation of Metacarpal Epiphyses.

Mr. H. L. Barnard* has published a description with a capital radiogram of separation of the epiphyses of the heads of the four outer metatarsal bones in a boy aged thirteen. The end of one diaphysis made a painful projection on the dorsum of the foot, and was removed by Mr. Mansell-Moullin.

* *British Medical Journal* (see radiogram), December 1, 1300, p. 1568.

(*d*) CONGENITAL AND OTHER BONY DEFORMITIES.

The underlying bone conditions of many deformities of the human body can be clearly demonstrated by means of the rays. Formerly it was possible to study such deformities only after death, and upon the dry bone, but radiography has now made ascertainable the actual state of affairs upon the living body.

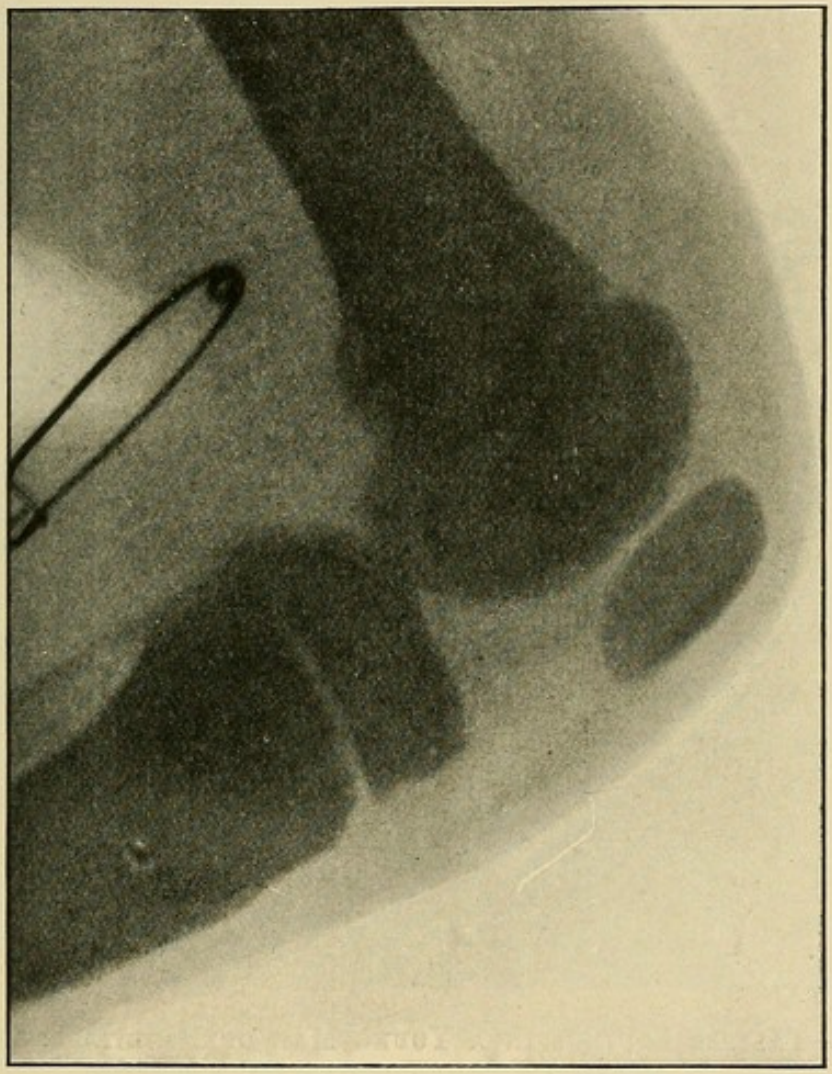


FIG. 120.—SHOWING REDUCTION OF LOWER FEMORAL EPIPHYSIS BY FLEXION. (*Medical Review.*)

It may be broadly stated with regard to such deformities that the Röntgen rays confer upon the surgeon the power of doing confidently that which formerly he was obliged to do tentatively—namely, to plan beforehand the mode and extent of his osseous operation. An excellent example of this general statement will be seen in the accompanying illustration (Fig. 121), reproduced by

permission of the *Lancet*.* Mr. Barwell says of it: 'The reader will perceive that the *x*-rays have marked out an abnormal length and a downward bend of the neck of the astragalus as being the obstacle to the restoration of proper form to the tarsal arch.' Fig. 122, also

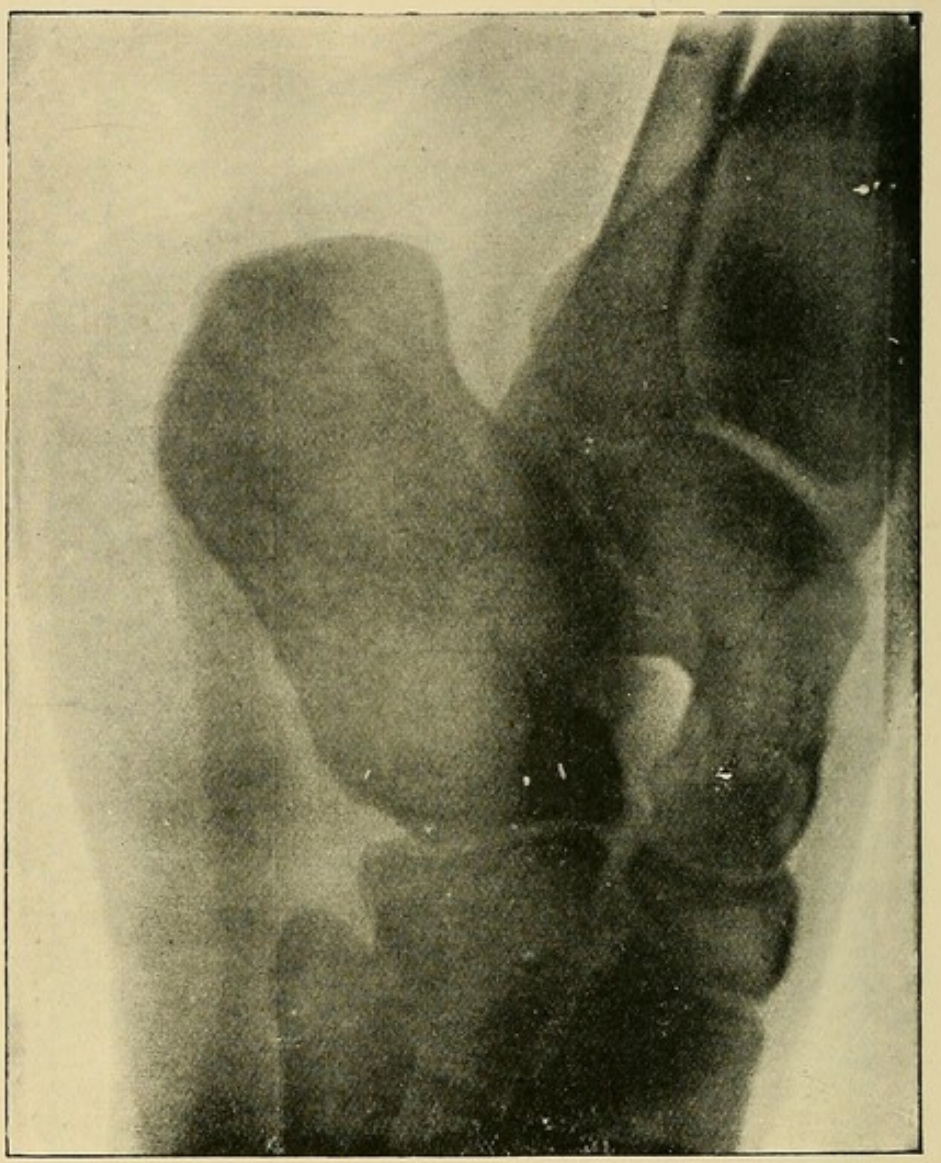


FIG. 121.—TALIPES EQUINUS IN A YOUNG MAN OF NINETEEN: DEFORMITY BEGAN AT THREE YEARS OF AGE.

Sydney Rowland. (*Lancet*.)

from the *Lancet*, gives an excellent illustration of a healthy foot bent strongly downwards.

In deformities of the spine the rays often afford valuable information. This is the more likely to be the case now that operations in that region are matters of everyday surgery. A good

* 'On Various Forms of Talipes as depicted by the *X*-Rays,' *Lancet*, 1896.

instance of the diagnostic value of the rays in cervical cases will be found mentioned under the section 'Diseases of Bone.'

Röntgen Rays in the Diagnosis of Spinal Disease.

Leyden and Grunmach* have shown that the *x*-rays are a valuable addition to our methods of diagnosis of spinal affections produced through diseases of the vertebræ.

In five cases of deformity of the spinal column accompanied by symptoms of paralysis the skiagraphs revealed characteristic lesions. In two cases of metastatic tumours of the vertebræ the diagnosis was confirmed by the *x*-rays. One case was cancer of the sixth and seventh cervical vertebræ, with spontaneous fracture secondary to mammary carcinoma. The other case was a sarcoma of the lumbar vertebræ secondary to sarcoma of the thigh. In two cases of injury to the spine the rays showed in one the presence of callus, and in the other a dark shadow, which was taken to be the remains of a hæmorrhage. They find, further, that cases of Pott's disease may be recognised early by means of the accompanying rarefaction of bony tissue. The spinal cord itself is quite transparent to the rays.

Dr. Carl Beck† read an interesting paper on congenital osseous malformations before the Diseases of Children Section at the annual meeting of the American Medical Association, 1901. Among other cases, he described one of a boy of five, in whom the rays showed one phalanx in the thumb and two phalanges each in the fingers. Operation secured a fairly good thumb. The same child had congenital fracture of radius and ulna in the lower third; the bones were wired, and perfect union was obtained. There was, furthermore, congenital constriction at the region of the surgical neck of the humerus, where a deep furrow encircled the whole circumference of the arm. Palpation detected no soft tissues between the integument and the bone. An exploratory incision revealed fragments of the biceps, triceps, and deltoid muscles, the edges of which were refreshed and united with catgut. A fair result was obtained fourteen months after operation. Another case showed congenital absence of the metatarsal and corresponding phalanges; another, congenital absence of nasal bones and arrested development of the nasal processes of the superior maxilla. One girl of nine years had

* *Neurologisches Centralblatt*, 1903, No. 1, p. 41.

† *Journal of the American Medical Association*, October 12, 1901.

congenital hypertrophy of all the toes, resembling elephantiasis, but shown by the radiogram to be of normal osseous structure.

The same author, in an earlier article,* described the radiographic appearances in a case of spina bifida in which the contents of the sac were to some extent differentiated.

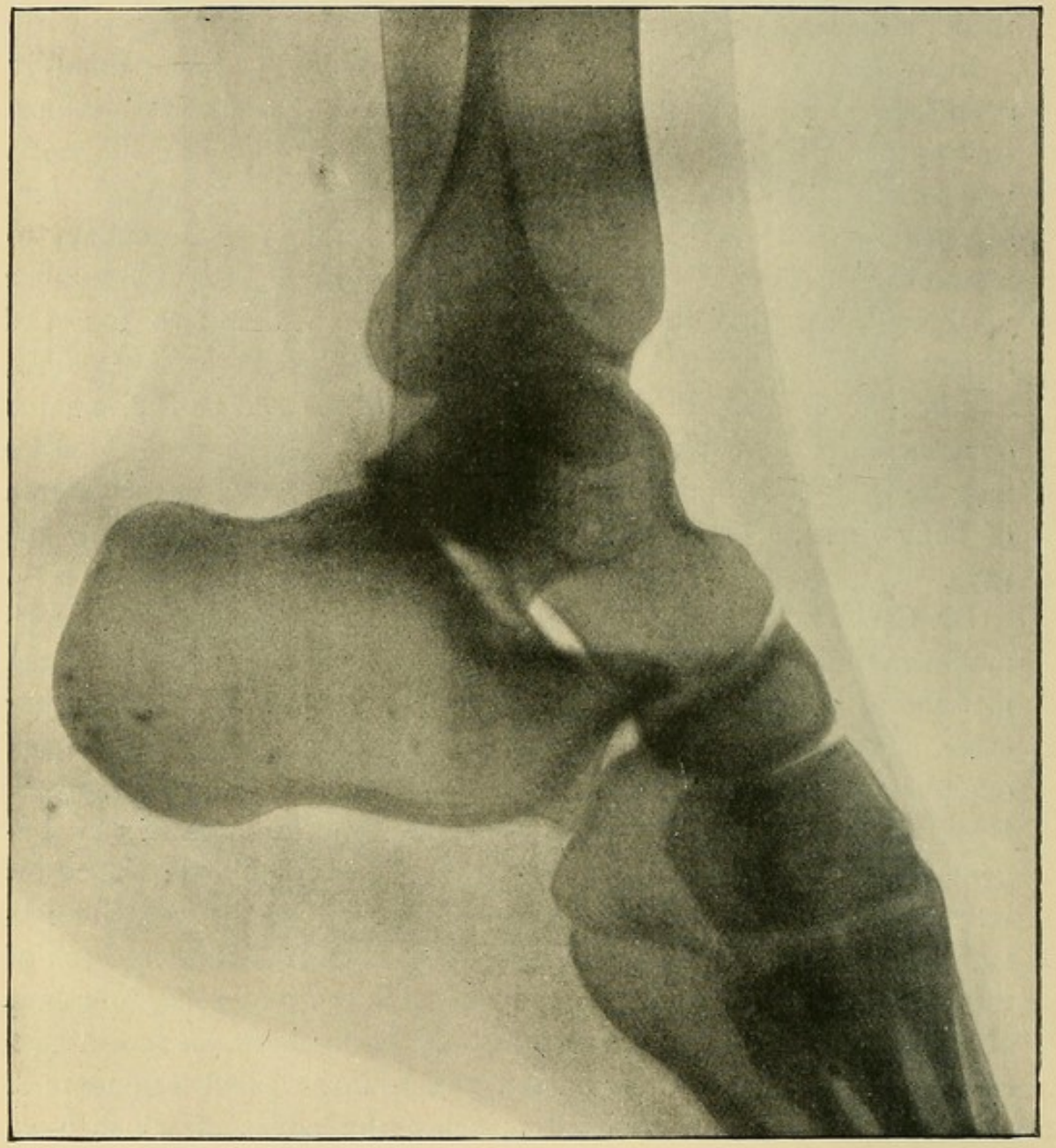


FIG. 122.—A NORMAL FOOT BENT STRONGLY DOWNWARDS.
Compare with preceding figure.

Numerous cases of polydactylism and allied congenital deformities have been published. In one or two instances the radiograph has

* *New York Medical Record*, August 13, 1898, p. 231.

indicated the appropriate line of operation upon supernumerary fingers and toes.

The writer appends an interesting example of polydactylism. The hands and feet in these illustrations are from the same subject. The hands appear to be wanting in fingers, but the radiogram shows that it is really a case of polydactylism, with supernumerary thumb. One of the missing fingers, the digit of the right hand, appears to be represented by a rudimentary phalanx forced down between the heads of the second and third metacarpal bones.

The feet, however, show suppression of toes, and suggest a two-toed type. The picture of the right foot is indistinct owing to trembling during the exposure. It is interesting to note that the other foot and the hands were not affected in a similar way, but were perfectly steady—a fact which may point to some local nerve instability or to some obscure electrical effect.

The two figures 123 and 127 are from a girl of twelve under Mr. Reeves at the Royal Orthopædic Hospital. The thumbs are absent in both hands—a rare congenital deficiency. In addition, the left arm, which is rudimentary and much shorter than the other, shows a remarkable condition of bony skeleton. Humerus, radius, and ulna are blended into one long bone, with an outstanding spur at the site of the obliterated elbow-joint. The fifth left metacarpal is partly developed.

Some interesting developmental defects with radiographic pictures were shown at the West London Medico-Chirurgical Society, March 3, 1899.* They included both proximal and distal deficiencies of the limbs. Four principal explanations have been advanced: (1) Interference with arteries; (2) nerve disturbance; (3) intra-uterine amputation; (4) reversion to ancestral type.

Dr. F. Winnett† has published an interesting case showing absence of second phalanges in toes, with presence of rudimentary second phalanges only in two of the fingers. The condition was congenital, and was present in mother, grandfather, great-grandfather, and great-great-grandfather. Only about half the members of each family were affected. Dr. Winnett remarks: 'It is difficult to understand how parts of so great antiquity, and not prone to variation like parts highly and unusually developed, or like vestigial structures, can be so modified.'

* *West London Med.-Chir. Journal*, April, 1899.

† *Canadian Journal of Medicine and Surgery*, September, 1901.



FIG. 123.—MR. REEVES'S CASE: THUMBLESS RIGHT HAND OF PATIENT IN FIG. 127. Dr. Walsh.

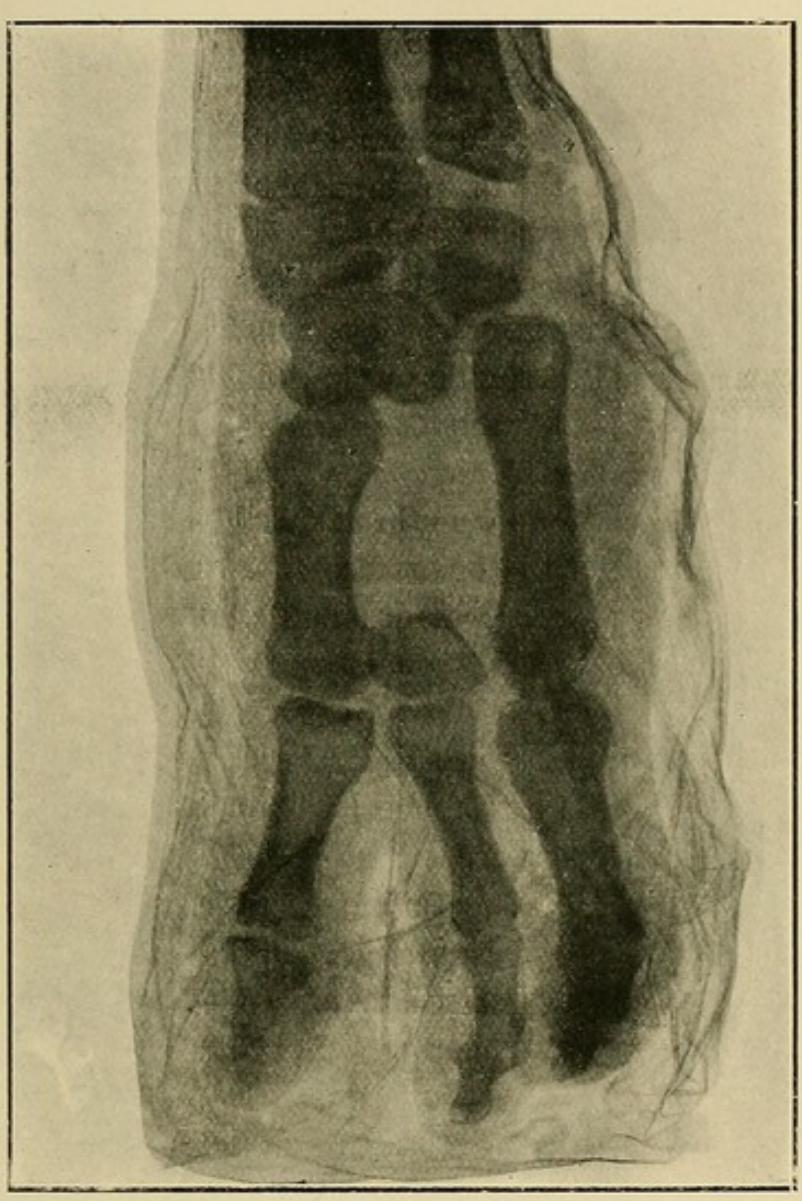


FIG. 124.—CONGENITAL ABSENCE OF FINGERS, INCLUDING METACARPALS AND DEFORMITY IN CARPUS. THE CENTRAL METACARPAL SHOWS ABSENCE OF SHAFT. THE FINGERS WERE WEBBED. THE HAND IS BANDAGED FOR OPERATION.

Dr. H. Cooper's case.

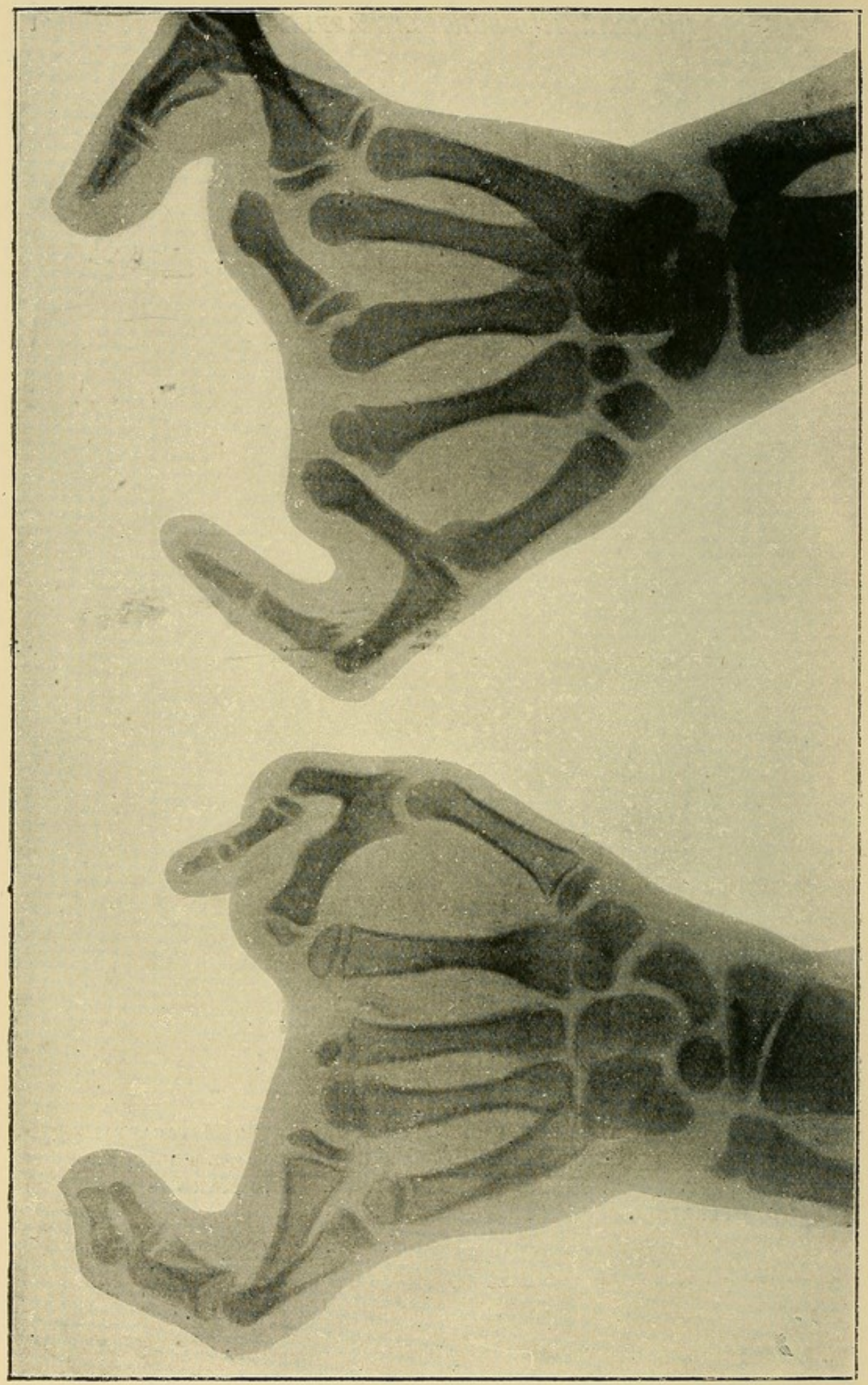


FIG. 125.—POLYDACTYLISM: HANDS OF A GIRL OF TWELVE.
Taken by Mr. Greenhill.

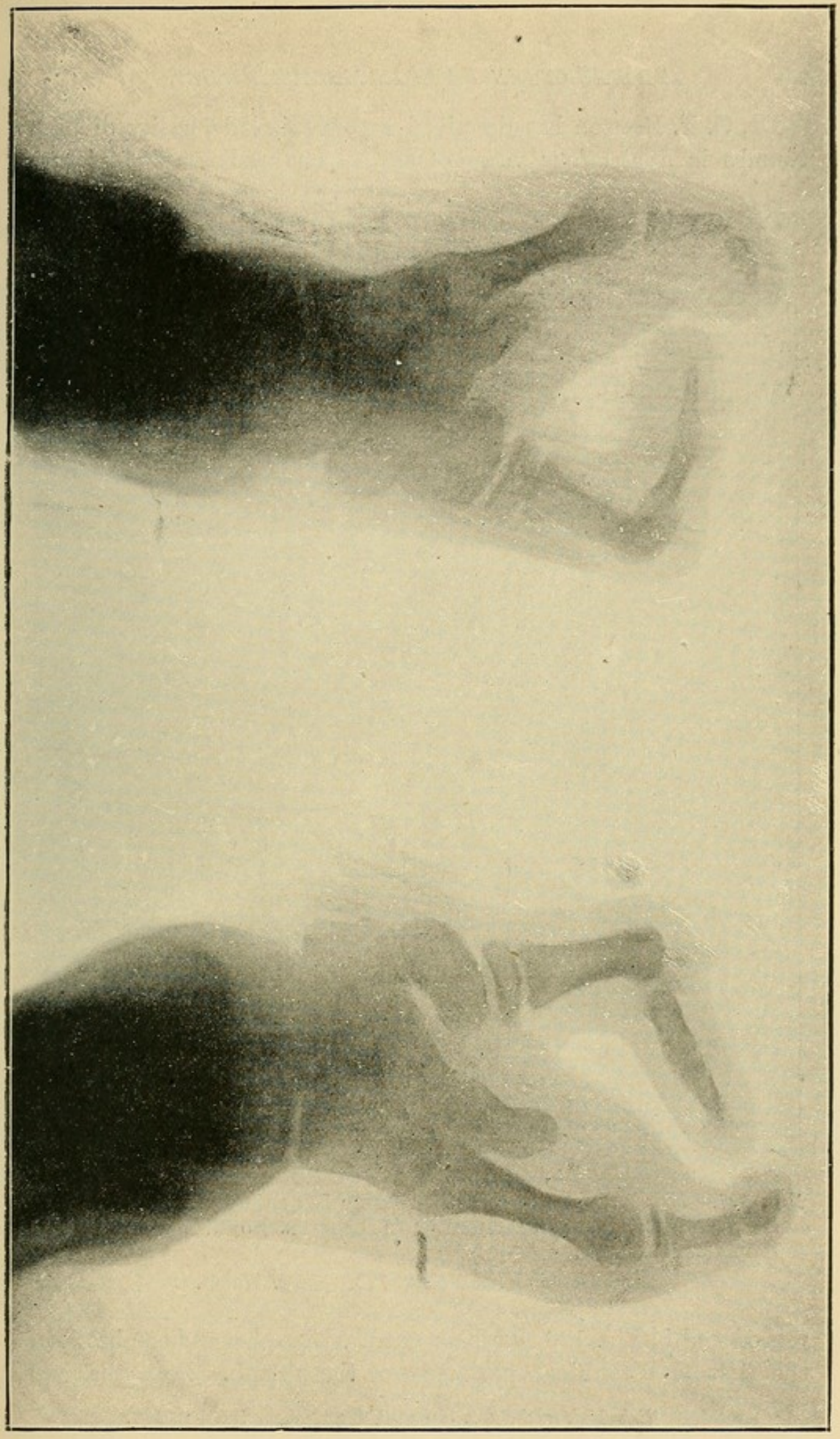


FIG. 126.—FEET OF SAME PATIENT, SHOWING SUPPRESSION OF TOES AND POSSIBLE REVERSION TO TWO-TOED TYPE.

Tremor of one foot during exposure

Dr. G. T. Beatson has described a congenital deformity of both thumbs in a girl four years of age.* The radiographic picture

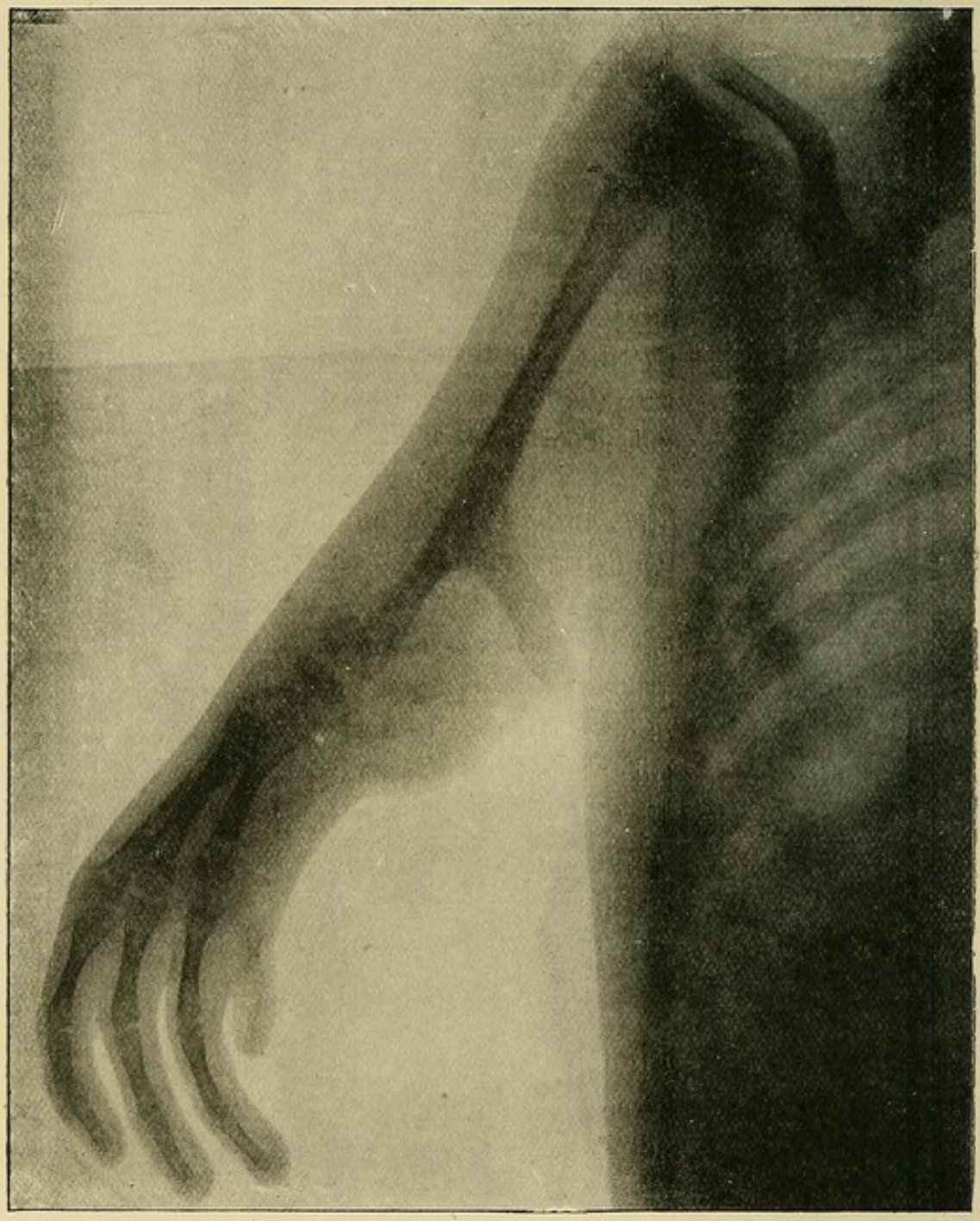


FIG. 127.—MR. REEVES'S CASE OF DEFORMED LEFT UPPER LIMB, SHOWING BONY OUTGROWTH FROM HUMERUS AND DEFICIENCY OF ELBOW-JOINT AND BONES OF FOREARM.

Right hand shown in Fig. 123. Dr. Walsh.

reproduced in Fig. 128 shows an extra wedge-shaped bone between the first and terminal phalanges of the thumb. Both the end

* *Scottish Med. and Surg. Journal*, September, 1901, p. 198.

phalanges were bifid. There was a family history of extra digits and toes, and broad thumb and great-toes, and also of webbing. The father's thumbs were not bifid at the end phalanges, but the terminal phalanx of one great-toe was partly bifid, with two

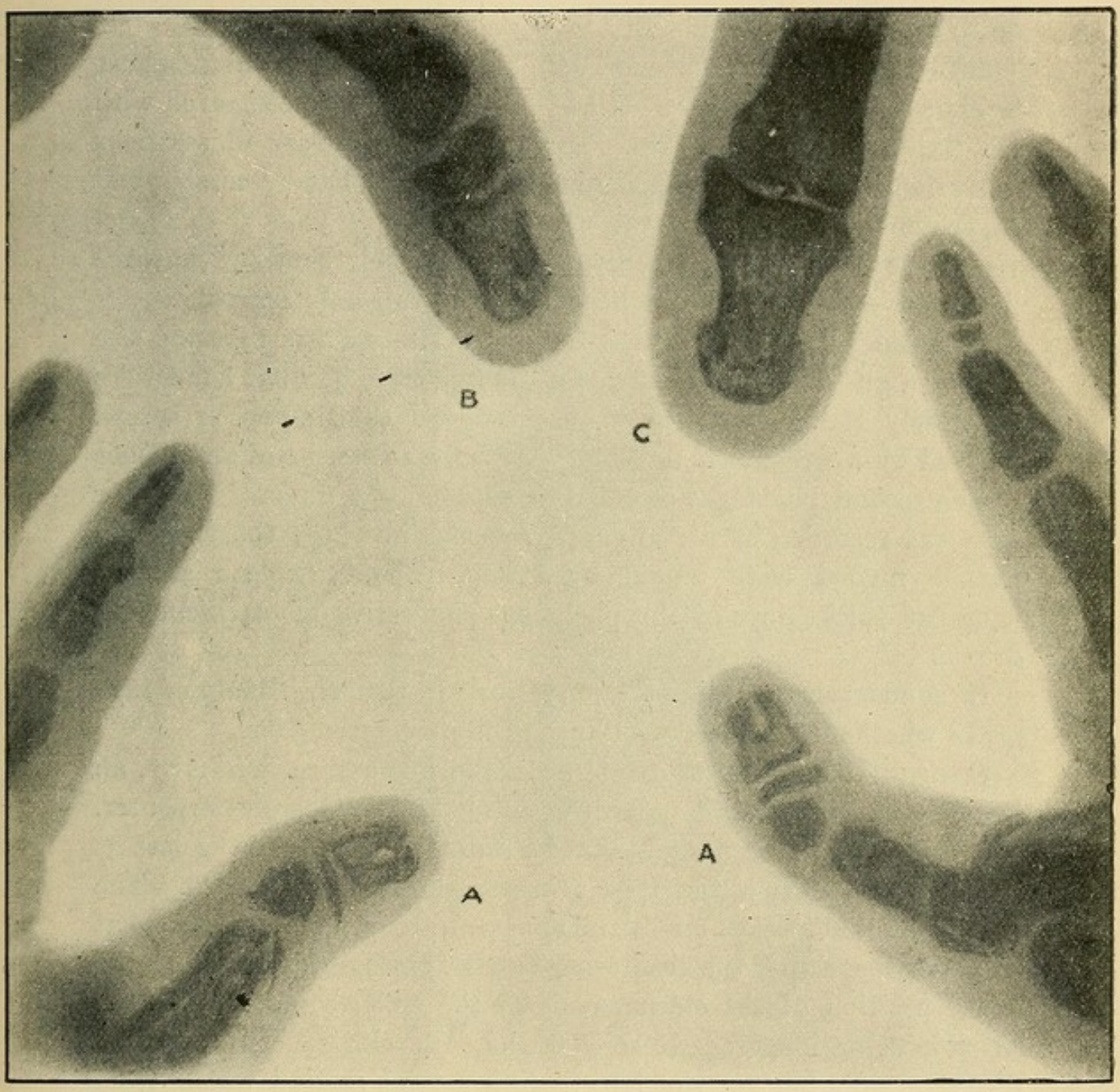


FIG. 128.—DR. BEATSON'S CASE OF BIFID TERMINAL THUMB PHALANGES.

distinct nails. Dr. Beatson quotes the statement of Coats that 'deformities of fingers and toes are to a certain extent interchangeable, the one being transmissible from the other.' He also mentions Gegenbauer's definition of the atavistic view, namely, 'the reappearance of a more primitive organization, or a reversion to a

primary state.' With regard to his own case, he considers it fair to assume that, looking to the family history of hyperdactyly, the extra bone found in the thumbs of his patient was the rudiment of another finger, and that the bifurcation of the ungual phalanx indicated how the process would have been completed had it gone on to a full termination.

Bifid Phalanx.—An excellent bifid terminal thumb phalanx is shown in the Röntgen Atlas.* This should be compared with Dr. Beatson's case (Fig. 128). In the same volume are illustrations of various other deformities, such as thumbless hands, missing and supernumerary digits, absent ulna, and so on. One plate (Tafel viii. 2) shows a supernumerary finger on each hand, with three phalanges articulated to the head of a bifid third metacarpal.

Syndactylism.—Dr. F. B. Lund,† of Boston, has reported the case of a girl of eighteen in whom the fingers of the left hand were so closely united that the hand resembled the fin-paw of a seal. Viewed by a screen, the deformity was seen to consist of an absence of the second phalanges of the fore and middle fingers. Another case was recorded of a man, aged seventy, in whom the ring and middle fingers were united by a web. The radiogram showed irregular thickenings of the phalanges suggestive of osteo-enchondroma.

In syndactylism an important feature is that the Röntgen rays prove whether its nature is cutaneous, fibrous, or osseous.

Congenital absence of the clavicle is a rare deformity, an instance of which was sent to the writer by Dr. George Carpenter. The following is the description of a radiogram taken of the case :‡

'Several abnormalities appear in the photographic record. The first point that strikes one is the apparent absence of clavicles; but on closer inspection the shadow of two fragments can be seen lying in the position of the sternal ends of the collar-bones, that on the left side being longer. No trace of the outer clavicle can be seen on the right side, but on the left there is a faint shadow which, from its size and position, suggests a cartilaginous rudimentary clavicle, with a more or less ossified inner end. The transverse process of the last cervical vertebra is so enlarged as to suggest a cervical rib.

'This patient, a girl of eight, also showed a depression in the upper

* 'Atlas der normalen und pathologischen Anatomie.' Ergänzungsheft 2, Tafel vii. 4.

† *Boston Med. and Surg. Journal*, December 18, 1902, p. 670.

‡ *Vide Lancet*, January 7, 1899.

part of the sternum. She could bring her shoulders together so as to meet in front of the chest. Her family presented the following abnormalities: Father had both clavicles in two pieces, the inner ends of the sternal fragments overriding. A brother, aged fourteen, showed a prominent arch forwards of left clavicle, and division of right clavicle, with inner fragment overriding; his last cervical transverse processes were prominent, especially on the right.



FIG. 129.—CONGENITAL ABSENCE OF FIBULA, WITH HYPER-EXTENSION OF FOOT.

Mr. Robert Jones's case. Dr. Morgan.

Another brother, aged nineteen, showed a prominent kink in both clavicles, but no division; his sternum showed a depression the size of half an orange. A sister, aged twelve years, had a divided right clavicle, with overlapping sternal fragment, and an enlarged right transverse process of the last cervical vertebra. Another brother, of sixteen, had normal clavicles, but enlarged lower transverse cervical processes. Another sister, of five, was normal. Lastly, a brother of seven had a divided right clavicle, the ends of which were closely united; both the lowest transverse cervical processes were prominent. There was a history of club-feet in two of the family.'

Dr. Carpenter gives references to seven published cases. To these may be added one described by Dr. Schorstein,* and published with an excellent full-page illustration of the plate taken at the London Hospital.

Congenital Absence of Fibula.

Mr. Robert Jones has kindly furnished an example of this rare deformity (Fig. 129).

Congenital Absence of Ribs.

A Case of Arrested Development of the Third and Fourth Ribs. Alfred G. Levy, M.D. Lond. (*British Medical Journal*, May 13, 1899.)

An interesting case of arrested development of the third and fourth ribs in a boy of thirteen years has been recorded by Dr. A. G.

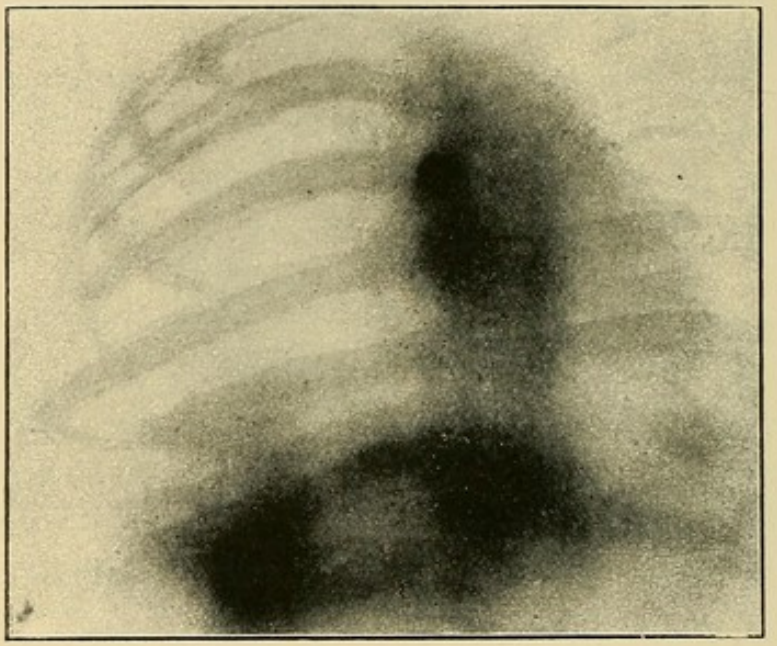


Fig. 130.—Deficiency of Ribs.

(From *Lancet*.) Dr. Levy's case.

Levy. The abnormality was on the right side, where the depression existed, due not only to the absence of the ribs, but also to that of the lower part of the pectoralis major. The clavicular portion of that muscle was exaggerated, together with a small portion arising from the first rib. There was no trace of pectoralis minor. The spine presented a well-marked dorsal curvature, with little compensation curve either in the lumbar or in the dorsal region.

* *Lancet*, January 7, 1899.

Dr. Levy gives the following description : 'The third rib cartilage is a little stump about ½ inch in length, but the fourth is a narrow curved strip 2½ inches long lying close along the upper border of the fifth cartilage. The end of the curtailed third rib may be obscurely felt in the axilla just under the margin of the pectoral muscle, and lying close to the second rib, while the attenuated termination of the fourth rib is found a little further back in the axilla.'

Dr. Levy, discussing this rare condition and its literature, says that complete absence of the ribs, usually the asternal ones, is now and then reported, and is sometimes associated with defectiveness or absence of the corresponding vertebra; 'but it would certainly appear that ribs tend more to vary in the direction of complete absence than in that of mere incompleteness of development.'

L. E. Herklet (*Journ. Anat. and Phys.*, London, 1896, vol. xxx.) states only five cases of absence of first rib are recorded in Great Britain, and Helm (*Anat. Anz.*, Jena, 1894-95, p. 50) finds only sixteen cases in general literature during the previous twenty-five years. Dr. Levy remarks that 'the rudimentary first ribs have been variously regarded as possessing developmental and even evolutionary significance, but instances of this retarded development of the other ribs are purely accidental faults, comparable to those occasionally found in all the other bones of the body.'

Congenital Elevation of Scapula and Humerus (Sprengel's Deformity).

Examples of this rare condition were shown at the Liverpool Medical Institution, December 5, 1901.

Congenital displacement of the scapula is little heard of in England and America, but is commonly reported in France. It was first described by Sprengel in 1890, and the deformity is known as Sprengel's deformity. It consists of an elevation of one scapula above the level of its fellow, usually with approximation of the lower angle to the middle line. The etiology of this affection is doubtful, but the probability is in favour of constrained fœtal position. In two cases seen by Sprengel soon after birth the arm appeared to have been fixed behind the child's back.

Mr. Jones has quoted literature and described a case * in which limitation of movement was due to structural shortening of muscles.

* *Liverpool Medico-Chirurgical Journal*, March, 1902.

In a second case the limitation was partly due to an extraneous portion of scapula articulating with the spinous process of one of the cervical vertebræ. In the latter case the extraneous portion of bone was removed, and resulted in considerable increase of scapular movement.

At the same meeting Mr. Robert Jones showed radiograms of a case of congenital dislocation of the shoulder, and quoted literature on the subject.

Cervical Ribs can be readily demonstrated by the rays. A good case has been described by Mr. Herbert Alderson, M.B.* The patient was a young lady twenty-one years of age, who complained of a swelling on the right side of the neck. A Röntgen photograph taken showed two cervical ribs, that on the left being rudimentary, and consisting merely of head, neck, and tubercle, articulating with the transverse process of the seventh cervical, but without a shaft. The right rib was more developed, and possessed a shaft that passed downwards beneath the clavicle to the first intercostal space, where it appeared to join the second rib by a cartilaginous union. The shaft was divided by what seemed to be a false joint, which, from the history, might have been the result of a fracture.

Mr. Alderson quotes Professor Gruber, who collected seventy-six cases of cervical ribs in forty-five individuals, recorded between the years 1740 and 1809. To that number he adds a case met with in 1830 by Dymock, and published in the *Edinburgh Medical and Surgical Journal*, vol. xl.; and another in 1896 by Warren, in the *Boston Medical and Surgical Journal*.

To the foregoing may be added two fully-recorded cases by Dr. Danlos and Dr. Bonnarme.† Both were on the left side, the anterior end being free in the one case, and in the other having a subclavicular attachment, which appears not to have been exactly defined, but did not involve the collar-bone.

Anatomically, the vertebra is developed from eight points of ossification, three of which are primary and five secondary. Sometimes it possesses an additional or costal centre of ossification. In the seventh cervical this makes its appearance in front of the transverse process, with which it usually unites about the fourth or fifth

* *British Medical Journal*, December 4, 1898, p. 1638.

† 'Les Rayons *X*.' Paris, Num. 2 et 3, Février, 1898.

year. The abnormal development of this costal centre constitutes the cervical rib.

M. Blanchard has classified cervical ribs thus :

1. A complete rib, extending direct from the seventh cervical vertebra to the sternum.
2. A rib with cartilage joining that of the first rib.
3. A rib with two osseous portions joined by fibrous tissue.
4. A rib with free end.

It is likely that cervical ribs are relatively more common than is recognised by anatomists, and that many such cases will be discovered by the Röntgen methods. The diagnosis is of some importance, as the abnormality may simulate aneurism or bony and other tumour, and may give rise to various symptoms by pressure upon nerves or bloodvessels.

An interesting case has been recorded by T. E. Gordon, M.B., Surgeon to the Adelaide Hospital, of obliteration of the arteries of the right arm and partial gangrene of fingers due to a cervical rib. A cervical rib on either side was disclosed by the radiogram,* that on the right being the higher and more horizontal. Excision of this right rib relieved the condition. The author classifies cases of cervical ribs under three headings : '(1) Where no symptoms are produced, and this is the largest class ; (2) where the rib gives rise to nervous symptoms only, such as wasting and loss of power, pain, and chilliness ; (3) where the leading symptoms are circulatory.' Of the last-mentioned rare condition the author collected seven cases.

The 'Small' Chinese Foot.

Two radiograms showing the deformity of a Chinese lady's foot, with a good note of the condition, have been published by Dr. J. Duncan Thomson,† of Hankow, China. Speaking of the illustrations, he writes :

'The first is that of a small foot, taken with the inner (tibial) side next the plate ; the second is that of a small foot, taken with the outer (fibular) side next the plate. The deformity is caused, on the one hand, by bending the arch of the foot so as to bring its ends (the heel and the balls of the toes) together ; and, on the other hand, by bending the four outer toes under the first or big

* For radiogram (taken by Dr. Clendinnen), see *Intercolonial Medical Journal of Australasia*, July 20, 1900.

† *British Medical Journal*, June 8, 1901, p. 1395.

toe. Compare now the skiagraphs, and it will be seen that the former procedure is to cause the joints on each side of the navicular bone to gape, to wedge up the cuboid, to overflex the ankle-joint, bringing the astragalus to lie almost at right angles to the leg bones, and the calcaneum to point downwards and backwards (in place of slightly upwards and backwards), and to bring the cuneiforms and metatarsals to point downwards almost parallel to the big bones. As this is begun during infancy, the development of the bones is arrested, notably that of the metatarsals, the cuboid, and the anterior end of the calcaneum. This arrest in development extends further to the bones and to the muscles of the leg. In those who take exercise the thighs are usually well developed. Owing to the difficulty in taking healthy exercise, however, it may be seen that in the majority the whole system may suffer, and that after many generations the race as a whole may be adversely affected, both physically and morally.'

Hallux Valgus and Varus.

Hallux valgus, in some instances, appears to be independent of boots. Cases may be classified as (*a*) congenital; (*b*) rheumatoid; (*c*) due to boots.

The dislocation of sesamoid bones that takes place in hallux valgus is shown by the *x*-rays in the interosseous space. These bones have been removed by some surgeons as the chief cause of the symptoms. Mr. John Poland has published some remarkable cases of hallux varus.

Deformity through Arrested Development.

Ateleiosis.—This peculiar disorder of development has been described by Mr. Hastings Gilford.* It is characterized by a delay of growth and development, and the consequent condition of dwarfism or infantism. A radiograph of the hand of a man, aged twenty-eight, the subject of ateleiosis, and whose height was 3 feet 7 inches, showed a condition of ossification such as is usually seen at from ten to twelve years. The length of the hand was 11·75 centimetres.

(*e*) DISEASES OF BONE.

As a bone casts a definite shadow under the Röntgen rays (when not obscured by the mass of surrounding tissues), it follows that

* The *Practitioner*, June, 1903, p. 804.

bony outgrowths will do the same. In this way one can get a good *x*-ray record of osseous thickenings and exostoses. An outstanding enchondroma, when it consists of pure cartilage, will throw a faint shadow with a short exposure. As the growth, however, becomes ossified, it gives rise to a denser tracing on the sensitive plate. Subperiosteal thickenings, as in syphilis, may be readily demonstrated by means of the rays, and also the hyperplastic conditions met with in ordinary periostitis, in rickets, and in Charcot's disease.

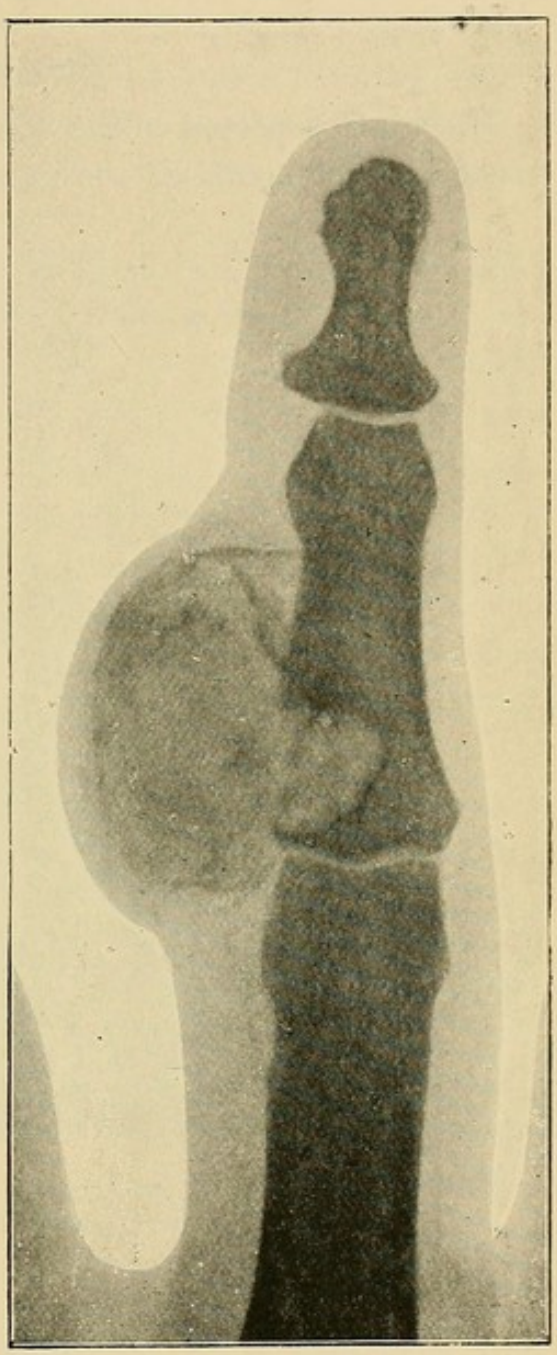


FIG. 131.—OSSIFYING ENCHONDROMA OF FINGER, OF OLD STANDING: FOLLOWING INJURY.

Messrs. Allen and Hanbury.

Exostosis, or Ossifying Enchondroma.

A good example of ossifying enchondroma is shown in Fig. 131. It was taken from a man of about fifty who had sustained an injury to the hand many years previously. In a ray photograph the tumour presented the appearance shown in the figure. From its generally light shade, we may assume it to be composed either of spongy bone or of cartilage that has undergone partial ossification, the areas of the latter being shown by darker mottlings. An interesting point is that the form of the growth is distinctly traceable where it overlies the darker phalanx. This lighter shade may be due to its replacing the compact tissue of the shaft by new spongy bone. A somewhat similar appearance is to be found in Fig. 68, where absorption of the outer shell of the bone has followed the impact of a bullet.

A good example of exostosis of the tibia causing pressure deformity and absorption of the fibula has been kindly contributed by Mr. Robert Jones, F.R.C.S., of Liverpool (see Fig. 132).

Gouty Bones.

M. Potain reported to the Paris Academy of Sciences the occurrence of light spots on the radiograms of gouty bones.* Presum-

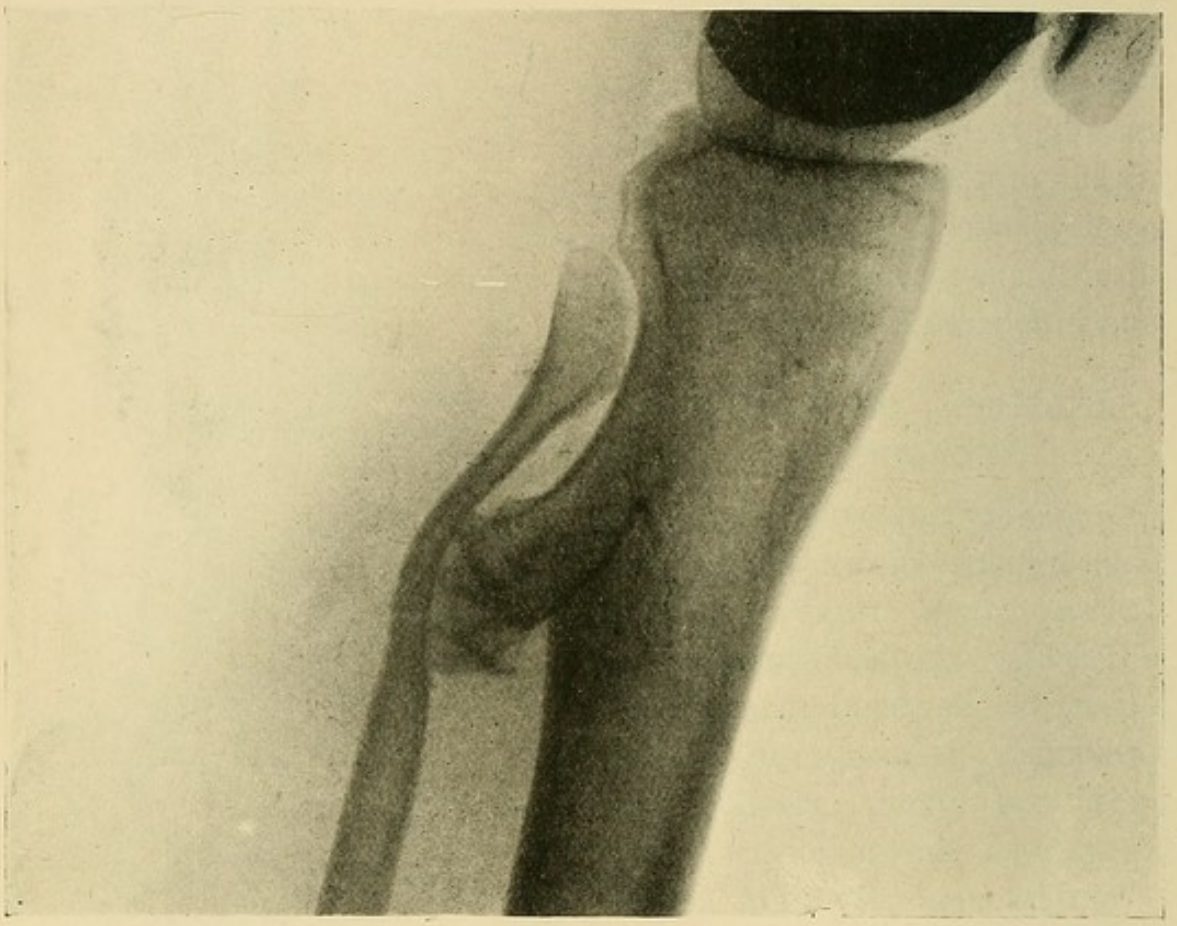


FIG. 132.—EXOSTOSIS OF TIBIA, CAUSING ABSORPTION AND DEFORMITY OF FIBULA.

Mr. Robert Jones's case. Taken by Dr. Morgan.

ably the compact tissue of the shaft altered at the point of projection of these tophi.

This gouty translucency, if such a term may be applied, was explained by M. Potain in the following ingenious and suggestive manner: 'The change appears to be due to the substitution of urates for phosphates of lime. Comparing the different salts which enter into the composition of bone, they are found to be differently permeable to the Röntgen rays. Phosphate and car-

* *Medical Press and Circular*, March 10, 1897, p. 249.

bonate of lime and chloride of sodium are little permeable, soda and magnesia more so, and urate of lime still more. By making use of two carboard boxes, the one filled with urate of lime and the other with tribasic phosphate, and submitting them simultaneously to radiography, it is easy to ascertain that the urate of lime is eight times more transparent than the phosphate, because a precisely similar shade is only to be found where the thickness of the latter is eight times less than that of the former.'

In gouty bones, then, M. Potain concluded that the points where urates are substituted for phosphates become more transparent to the Röntgen rays. He further stated that the osseous thickenings due to chronic rheumatism or rheumatoid changes had an increased opacity. If these observations be correct, it follows that it is possible by means of the focus-tube to distinguish whether bony enlargements are the result of gouty or of rheumatoid changes. Assuming that the latter enlargements are more opaque, that condition must be carefully distinguished from the general atrophic state of the bones mentioned when discussing the hand affected with chronic rheumatoid arthritis, shown below in Fig. 134.

M. Potain has made the following practical application of his conclusions: 'In subjects affected with nodosities of Heberden, a lesion of which the gouty nature is still a debated question, very distinct transparent spots are found at the level of the phalanges, which appear to decide the dispute in favour of those who consider gout the primary origin of the affection.'

A marked example of extreme gouty deformity came under the writer's care. The patient was a painter about fifty years of age. Both hands were greatly deformed by gouty deposits and joint changes. The extent of the deformity may be inferred from the outline of the accompanying radiogram, and from the changes in the bone. The gouty changes were principally confined to the hands, a fact that may possibly have had some connection with his calling. He was under hot-air treatment as a hospital patient, and the present writer opened and scraped many gouty abscesses with much improvement to the appearance and the mobility of the hands. Since that time an improved operative treatment by dissecting away the infiltrated capsules of the joint has been introduced. The haziness of the radiogram is due to general uratic deposit. Some joints have become anchylosed, and in places the bones have been eroded by the gouty process.

Gummata and other Subperiosteal Thickenings.

The phalangeal enlargement met with in rachitic dactylitis described by Dr. Jacob Sobel, of New York, has been shown by

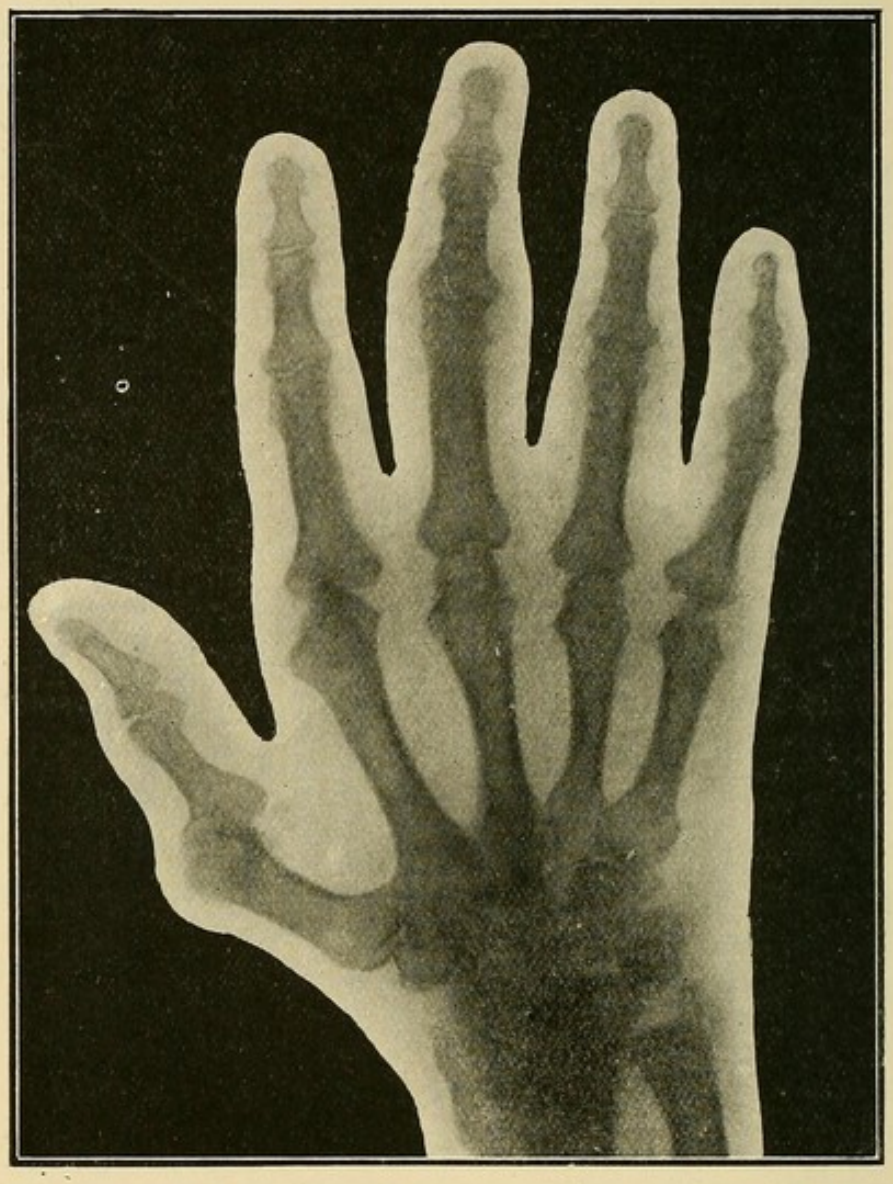


FIG. 133.—GOUTY HAND, WITH ATROPHIC DESTRUCTION OF BONE AND JOINTS, ANCHYLOSIS, DISLOCATION, ETC.
Walsh.

Dr. Rudolph Newrath,* who examined several cases with the *x*-rays, to be entirely due to periosteal thickening.

As regards the outlines of bones, the Röntgen rays are useful in the hypertrophies due to syphilis, enchondroma, rickets, gout, and rheumatism, and also in the important class of subperiosteal thickenings. A beautiful example of a gumma of the ulna was

* *Wiener Klin. Woch.*, June 4, 1903.



FIG. 134.—HAND DEFORMED BY CHRONIC 'RHEUMATOID' OR OSTEO-ARTHRITIS.

Somewhat reduced. Dr. J. R. Philpot's case.

exhibited at the 1898 meeting of the British Medical Association by Drs. Rainy and Stiles. It showed an irregular* erosion of bone in the centre of the growth, and a fresh formation (sclerosing osteitis) at the edges, and presented a clear picture of the macroscopical changes that were taking place.

Rheumatoid Arthritis.

The opacity of the rheumatoid peri-articular deposit is often well shown in a stiff ankle, while the opposite or general atrophic condition in the same disease is conspicuous in the accompanying radiogram, which is of interest as having been taken in the early days of radiography (Fig. 134).

The subject of the photograph was a lady, aged thirty-one, who was attacked with the disease at the age of thirteen. Her father and mother both suffered from rheumatism, and a sister from osteo-arthritis. Her lower extremities were first affected, but later almost every joint of the body had been invaded, and some permanently stiffened.

On comparing the bones shown in this radiogram with those of a healthy hand, a marked difference will be at once detected. The rheumatoid bones are atrophied, and it may be safely inferred that they are deficient in bone salts. Their outline is sharper and darker than normal—'pencilled'—and their substance lighter. Their relatively small size—that is, for a person of that age—is doubtless due to the arrest of development from early disturbed nutrition. Their greater transparency can be best seen in the fifth metacarpal, whereas the darker look of other bones is explained by the greater amount of tissue to be penetrated on account of the clawed-up hand. It will also be noticed that the bosses of ossified peri-articular cartilage on the phalanges are much of the same shade as the body of the bone. All the fingers are dislocated from the metacarpals. The base of the first phalanx of the fore-finger is apparently fixed against the distal ends of the second and third metacarpals, but the bases of the middle and third fingers appear to be partly wedged between the third and fourth and the fourth and fifth metacarpal heads respectively. The plate shows how a radiogram affords anatomical data for the explanation of such deformities.

Mr. Espin, of Newcastle, has noted a similar transparency in the

* *Lancet*, April 15, 1899.

bones of tuberculous subjects. In one case—that of a youth of sixteen, with a locked wrist following injury—he found 'the bones of the carpus ill-defined, and the ulna and radius, metacarpal bones and phalanges, abnormally transparent.' The transparency was in marked contrast with the appearance of the bones of the other wrist. His second case was that of a young man whose radius had been previously removed for tubercular disease, and who had also suffered from a tubercular abscess. On examination, he found that all the bones of both arms and legs showed an abnormal transparency.

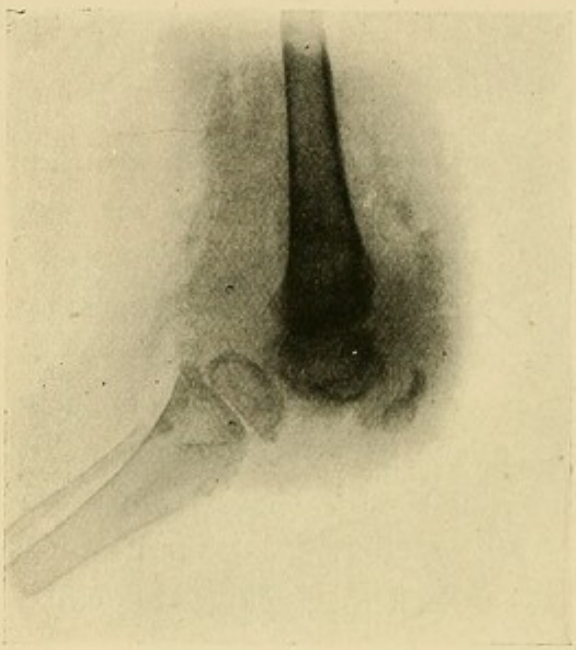


FIG. 135.—ANCHYLOSIS OF KNEE IN A BOY AGED FOUR YEARS AND NINE MONTHS, DUE TO TUBERCULOSIS.
Note atrophied bones of legs.
Mr. Robert Jones's case. Dr. Morgan.

Fig. 135 shows a beautiful instance of atrophic bones of the leg connected with tubercular anchylosis of knee in a child four years and nine months old. For this and other most excellent illustrations of bone conditions the author has to thank Mr. Robert Jones, F.R.C.S., of Liverpool.

Transparency, denoting malnutrition or atrophic changes, has been noted by various observers in such maladies as osteo-arthritis, osteomalacia, tubercle, and cancer, and also in the course of senile decay. It is a marked characteristic of rickets.

Post-Traumatic Atrophy of Bone.

Dr. Weigel,* at a meeting of the Section of Orthopædic Surgery, of the New York Academy of Medicine, has called attention to a peculiar atrophic condition of bones following injury, and discoverable only by means of the *x*-rays. The size and contour of the bones remain unaltered, while the spongy portion becomes rarefied and transparent, and the compact layer is thinned.

* Meeting of the New York Academy of Medicine, October 17, 1902.

Mr. Robert Jones has placed several good instances of secondary traumatic changes of bone at the author's disposal. One of these (Fig. 138) shows necrosis following fracture of the lower third of the tibia. The bones of the foot show mottling and pencilled outline.

This transparency of bone is accompanied by a pencilling of outline due to contrast of the compact outer layer with that of the rarefied cancellous tissue. Mr. Robert Jones, F.R.C.S., of Liverpool, has described this condition, and shows that disease of a limb rapidly induces atrophy and pencilled outline. He has kindly placed at the disposal of the author some excellent radiograms illustrative of this observation.

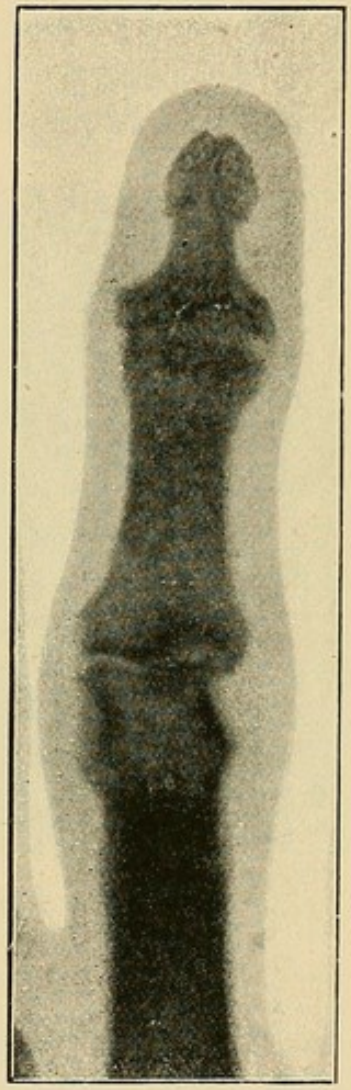


FIG. 136.—FINGER OF CRICKETER, SHOWING ABSORPTION OF BONE AND FIBROUS ADHESIONS OF JOINT (IN 1896).

Absorption and Abscess of Bone.

An instance of absorption of bone, apparently after abscess, is the following: The patient, a healthy man, about thirty years of age, was struck by a cricket-ball at the end of the right ring-finger, which was painful and swollen for several months, and ultimately became stiff. Except for some awkwardness in writing, he suffered little inconvenience from the resulting deformity. A radiogram showed osseous union at the terminal joint of the affected finger, while the base of the second phalanx was hollowed out, apparently as the result of an abscess. From the view here given (Fig. 136) it can be inferred that any union between the radial half of the joint surfaces is fibrous, while that on the ulnar side is probably of the same nature.

The bony changes that take place in the various pulmonary and non-pulmonary osteo-arthropathies can be well demonstrated. A good Röntgen photograph of the hypertrophic non-pulmonary form of that condition was shown at the Edinburgh British Medical

Association meeting by Dr. Steven of Glasgow. The differing texture of the new and the original bone was well demonstrated in the record of the fresh osseous formation round the shafts of the radius and the metacarpal bones.

Subperiosteal Thickenings.

Bony thickening under the periosteum, as a rule, is clearly shown by the *x*-rays. They may be of traumatic (Fig. 138), syphilitic (Fig. 140), tubercular, or of other origin.

In subperiosteal thickenings the differing density of the new and



FIG. 137.—KNEE IN HÆMOPHILIA.

Dr. Shaw's case.

the old bone is readily revealed by Röntgen methods. This contrast is especially conspicuous in cases where necrosis of the shaft is surrounded by an irritative hyperplasia of periosteal bone.

Hæmophilic Bone Conditions.

The joint changes met with in hæmophilia can be studied conveniently by means of the rays. These enlargements are not infrequently diagnosed in cases of tubercular arthritis until the diagnosis is cleared up by aspiration. In one instance* a leg was amputated under the impression that the knee was affected

* *Medical Records*, 1896, xlix., 336.

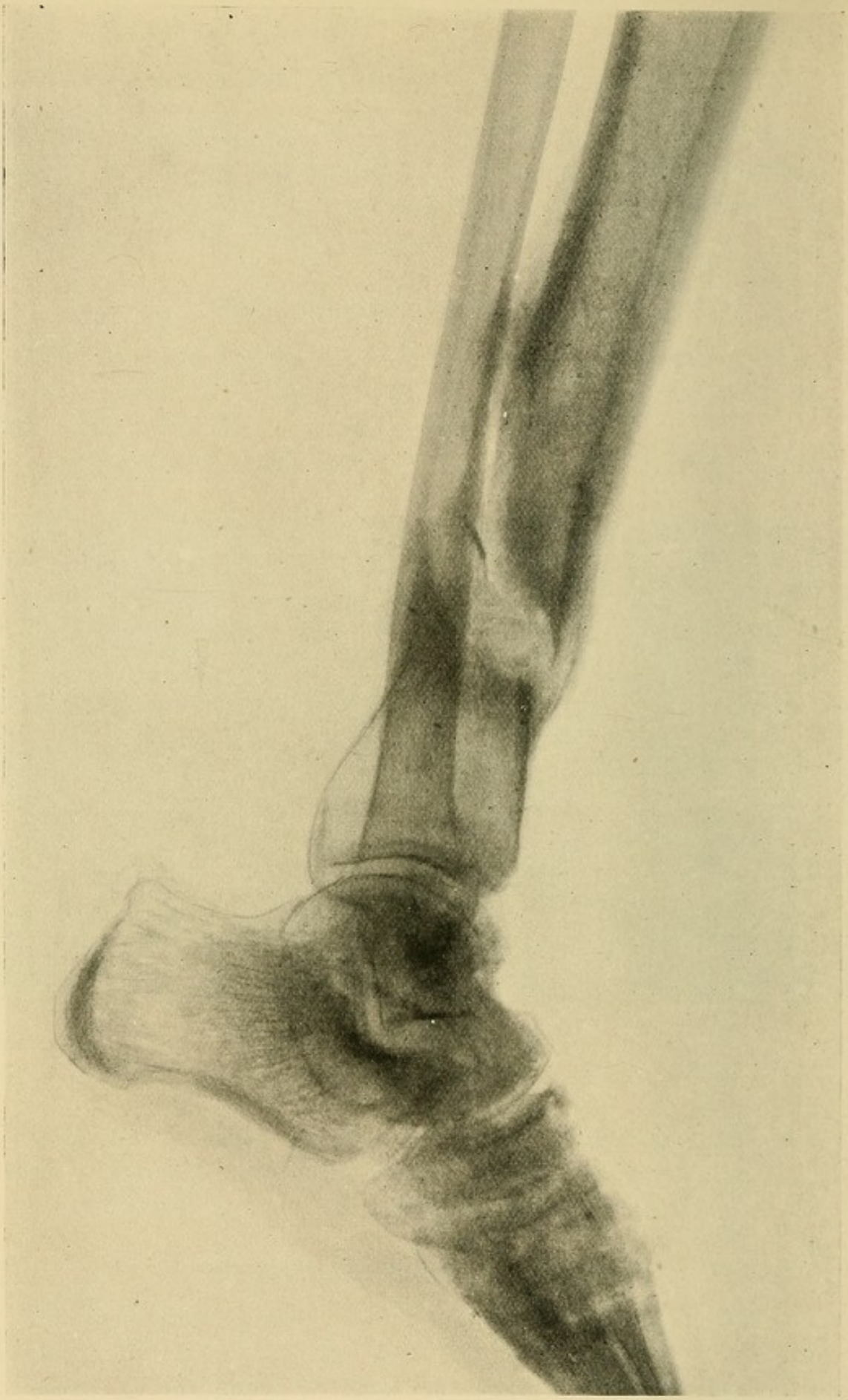


Fig. 138.—Fracture of Lower Third of Tibia, followed by Necrosis. The Bones of Foot show Pencilled Outline and Mottling of Cancellous Tissue.

Mr. Robert Jones's case. Dr. Morgan.

with quiescent tubercular arthritis, and the patient, a boy of ten, died twenty-four hours later from uncontrollable hæmorrhage. Dr. Shaw gives an account of a case in the *Bristol Medico-Chirurgical Journal* (September, 1897). He describes enlargement of elbows and knees, which were attacked with acute recurrent periarticular effusions, preceded by sensory phenomena. The afflicted joints were found on examination to be in a condition similar to that of osteo-arthritis, but, unlike that disease, the fingers and toes were attacked. The articular ends of the bones were much enlarged, the cartilages extensively absorbed, with well-marked 'lipping' (osteoplasia) at the edges of the articular surfaces. An accompanying Röntgen photograph showed great enlargement of the head of the radius, some lipping at the edge of the sigmoid fossa of the ulna, and thinning of the articular cartilages. Other papers referred to are by Greig Smith (*Bristol Medico-Chirurgical Journal*, 1884, ii. 264) and Bowlby (*St. Bartholomew's Hospital Reports*, 1890, xxvi. 77).

Congenital Hæmophilia.

Dr. F. J. Clendinnen,* of Melbourne, has published a good skiagram, showing the rare condition of congenital hæmophilia. The infant was prematurely born (at eight months), and at eleven weeks of age developed a tender swelling of the right hip. The skiagram showed the bones intact, but a general opacity in and around the joint, with the head of the femur separated from the acetabular cavity. The child developed another swelling in the shoulder, and died some days later. The diagnosis of hæmorrhage into the joints was aided by the passage of some dark tarry motions.

At the conversazione of the Röntgen Society in November, 1898, the author showed an *x*-ray photograph of two knees, one of which was subject to recurrent hæmophilic attacks. The affected joint was hazy and indistinct in contrast to the sharp definition of its sound fellow. A similar haziness is met with in other chronic periarticular affections, as in the osteo-arthritis and tubercular synovitis, also in inflamed pleura and rheumatic muscles.

* *Intercolonial Journal of Australasia*, August 20, 1901, p. 389 (with good illustration).

Rickets.

The bone changes in rickets are well marked and readily radiographed. A good example of the condition has been kindly furnished by Mr. Robert Jones (Fig. 139).

Scurvy Rickets.

An excellent full-page illustration of a fractured femur in scurvy rickets has been published by Mr. C. G. Burton,* late of the North-

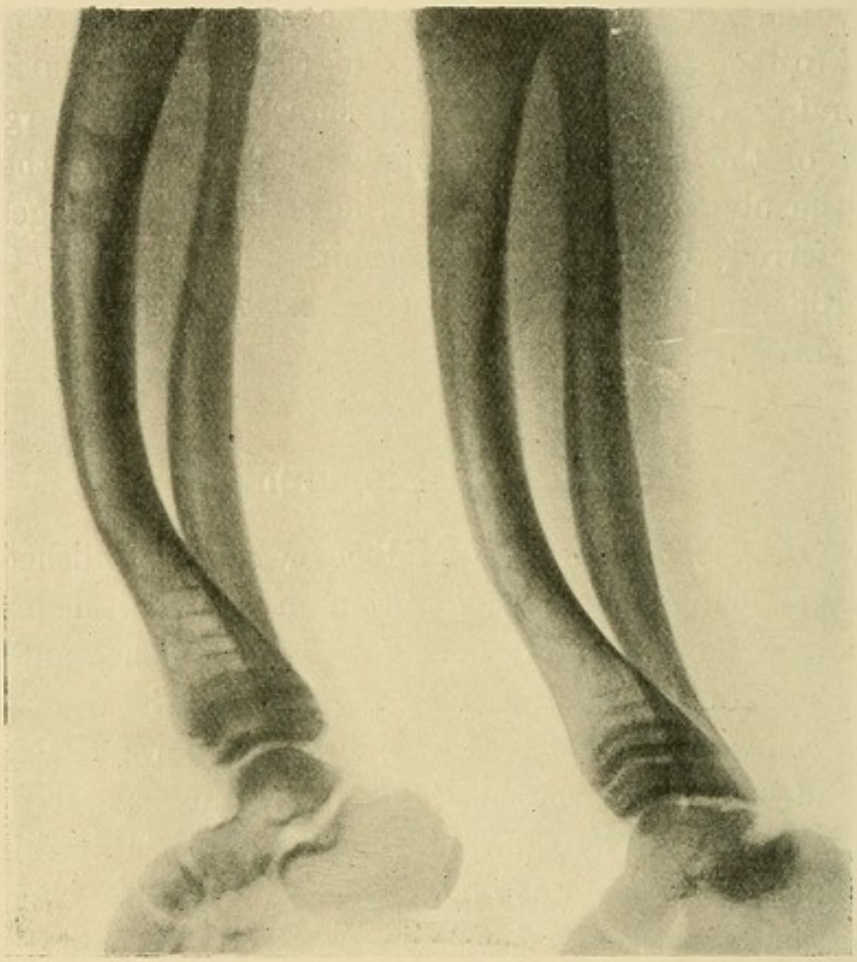


FIG. 139.—RACHITIC DEFORMITY IN CHILD OF TEN YEARS.
Mr. Robert Jones's case. Dr. Morgan.

Eastern Hospital for Children, London. It illustrates the bending and fracture of the bone in this rare condition, as well as the thinning of the compact wall of the femur and the rarefaction of the cancellous tissue.

Late Rickets.

An interesting case of a girl aged seventeen, in whom rickets appeared at five years, has been published by Mr. E. Muirhead

* *Hospital*, October 7, 1899, p. 6.

Little, F.R.C.S.* The patient wore splints and other supports from five years of age; at seven she took to crutches; at eight she fell and broke the right thigh above the knee, and afterwards the left. The deformity was chiefly in the femora; with their internal condyles touching, the distance between the internal malleoli was 14 inches. The lower ends of the femora curved backwards, and bent the legs at an angle of 75°. One of Mr. Little's chief reasons for calling the case 'late rickets' was the condition of the lower epiphyses of the forearm, as shown by radiograms. 'Instead of the narrow, clearly-defined zone separating the shadows of the diaphysis and epiphysis,' he writes, 'a wide, ill-defined blurred space intervenes. In this space irregular deposits of lime-salts have produced dark streaks in the print. At the same time there appears to be some tendency to "cupping" of the bony ends of the diaphyses.'

Caries of Bone.

Mr. Noble Smith† published an interesting case in which disease of the cervical spine was revealed by the radiograph. Various diagnoses had been made of the patient's condition—as, for example, hysteria. The Röntgen photograph, however, disclosed an irregular mass of bone replacing the upper four vertebræ of the neck. This evidence proved the existence of a severe lesion that had undergone extensive repair. Not only did it clear up the diagnosis of an obscure case, but it also yielded important indications for future treatment.

In another case recorded by the same surgeon, a provisional diagnosis of caries of the cervical vertebræ had been suggested by the presence of torticollis and other signs and symptoms. However, the radiogram showed conclusively that the spine was not affected. This negative result warranted alternative positive conclusions as to the nature of the malady.

Osteo-myelitis may be demonstrated by the rays. However, as pointed out by Geissler, the rarefactive change is sometimes obscured by the shadow of the overlying necrotic layer. Dr. Eugene H. Eising,‡ Assistant Radiographer to the Mount Sinai Hospital, New York, states that the area of disease in osteo-myelitis presents a

* *Medical Press and Circular*, May 23, 1900.
† *British Medical Journal*, 1896.
‡ *Medical Record*, New York, June 4, 1904, p. 909.

characteristic 'mottled' appearance, owing to irregular translucency produced by foci of liquefaction. Periosteal involucra, if present, will stand out prominently.

The bone changes of osteo-arthritis were well illustrated by a case reported to the Paris Académie des Sciences by Professor Lannelongue.* A patient at the Hôpital Trousseau had been affected for several years with an osteo-arthritis of the knee-joint, which was anchylosed in an extended position. The diagnosis was

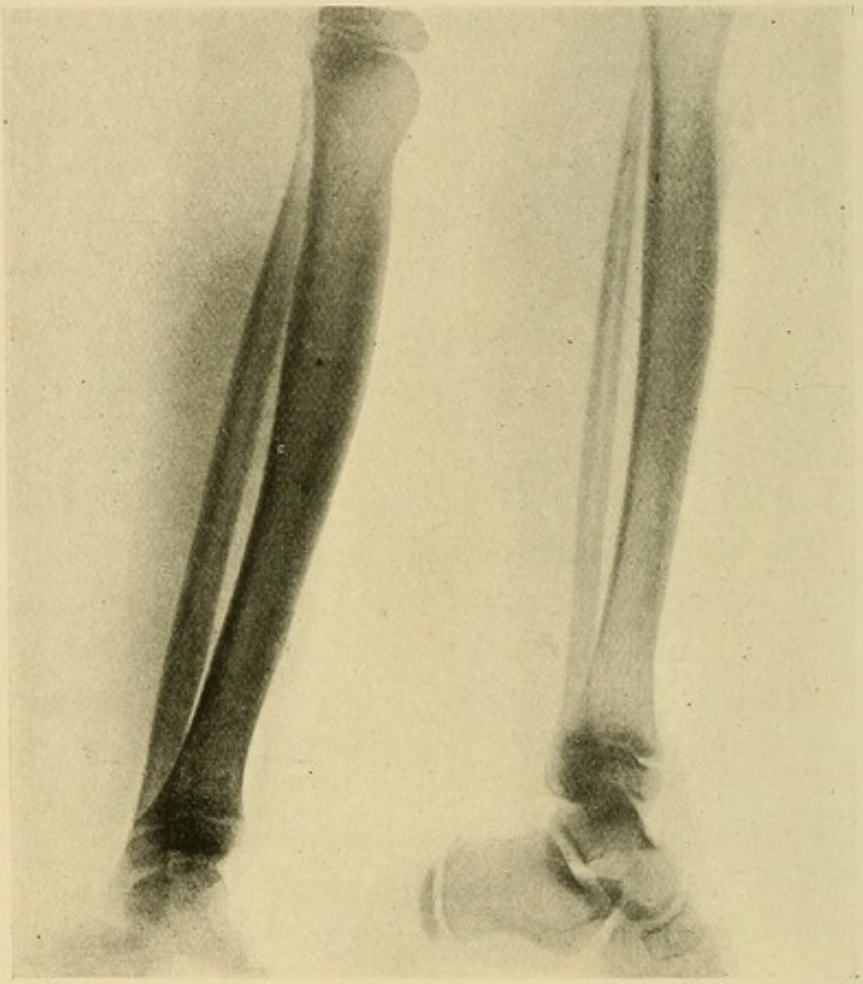


FIG. 140.—THICKENED TIBIA IN GIRL OF EIGHT YEARS, DUE TO SYPHILIS.
Mr. Robert Jones's case. Dr. Morgan.

fully confirmed by a radiogram, which showed hypertrophy of the lower end of the femur, together with atrophy of the upper epiphysis of the tibia. Between the two bones a light interval proved the absence of a bony union.

In a stiff joint, bony anchylosis usually shows under the rays as

* Paris Thèse, No. 53, D. 23, Louis Laurent.

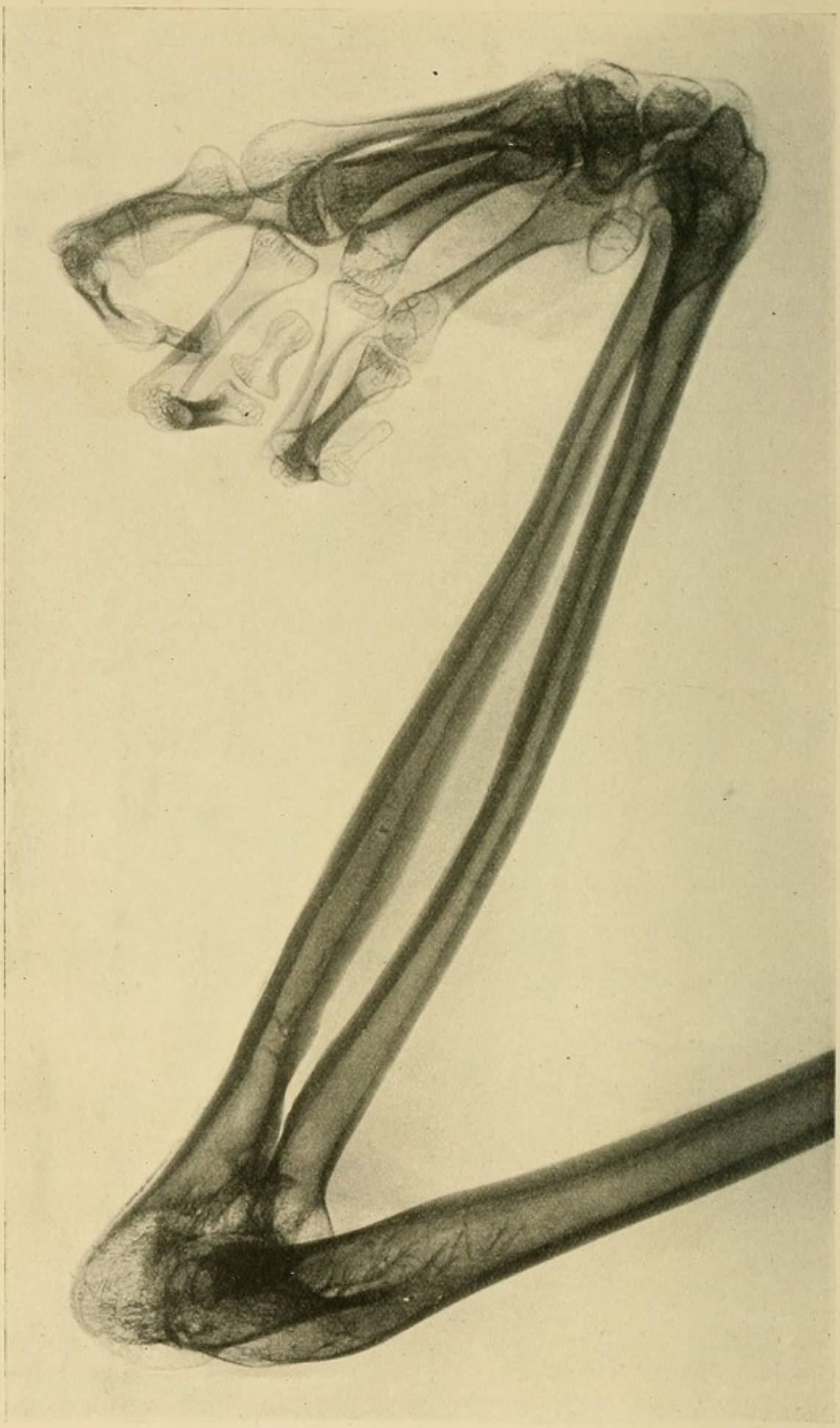


FIG. 141.—ANCHYLOSIS OF ELBOW AND CONTRACTION OF HAND IN YOUTH AGED EIGHTEEN: CONGENITAL SYPHILIS.

Mr. Robert Jones's case. Dr. D. Morgan.

a continuity of osseous structure that is unmistakable. On the other hand, fibrous union, as we have seen, is inferred from the negative evidence of a light interval between the articular surfaces. Dr. Joachimsthal, of Berlin,* mentions a case in which a boy of sixteen had the knee excised. The site of the operation was examined by the Röntgen method eighteen years later, when the bones of the leg and thigh were seen to be welded together into

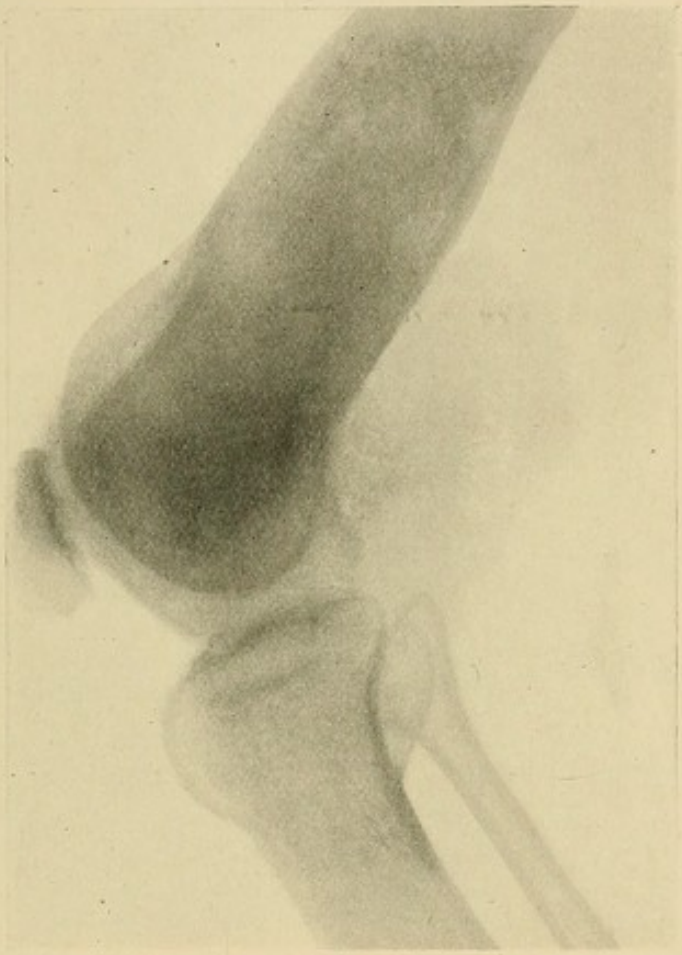


FIG. 142.—ABSCESS OF FEMUR IN MAN AGED FORTY-NINE YEARS. (NOTE TRANSLUCENT BONES OF LEGS.)
Mr. Robert Jones's case. Dr. Morgan.

one solid bone, bent at an obtuse angle. The compact tissue at the edges and the bars of the cancellous tissue both showed a perfect continuity. This adaptation afforded a good example of the change of structure and form that may follow altered function.

Fig. 141 shows a fine example of bony anchylosis of the elbow and syphilitic bone disease in a boy of eighteen.

* *Therapeutische Monats.*, February, 1897.

Abscess of Bone.

On account of the difficulty that sometimes occurs of diagnosing and of localising abscess of bone, it is fortunate that the condition can, as a rule, be demonstrated by the rays. Three most excellent examples have been kindly furnished by Mr. Robert Jones (Figs. 142-144).

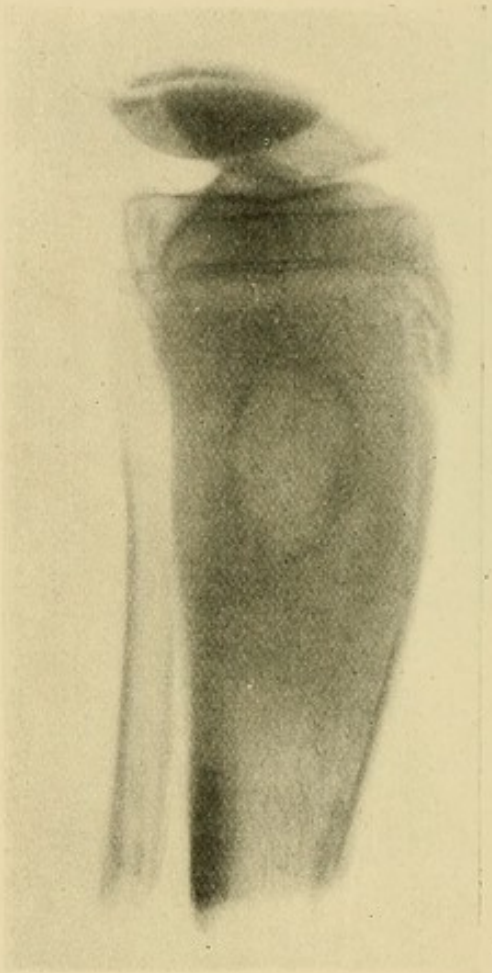


FIG. 143.—ABSCESS CAVITY IN TIBIA (BEGAN SUPERFICIALLY).
Mr. Robert Jones's case. Dr. D. Morgan.

The record of the abscess cavity should be carefully compared with the more sharply outlined cyst of ulna (Fig. 145).

New growths in the substance of bone may at times be photographed by the Röntgen rays. The first case of the kind was recorded by König, who found a bright spot, with dark contour, the size of a shilling, in the upper part of the tibia, to be due to sarcoma. Since that time many sarcomata of bone, central and otherwise, have been reported, some of them accompanied with fracture.

Osteopsathyrosis.

The rare condition of osteopsathyrosis, or fragilitas ossium, is met with in two chief types, one beginning in childhood and tending to improve in later years, the other starting in adult life and tending to persist until death. Dr. Montgomery H. Biggs* has published a case in which the patient, at the age of twenty years, broke his

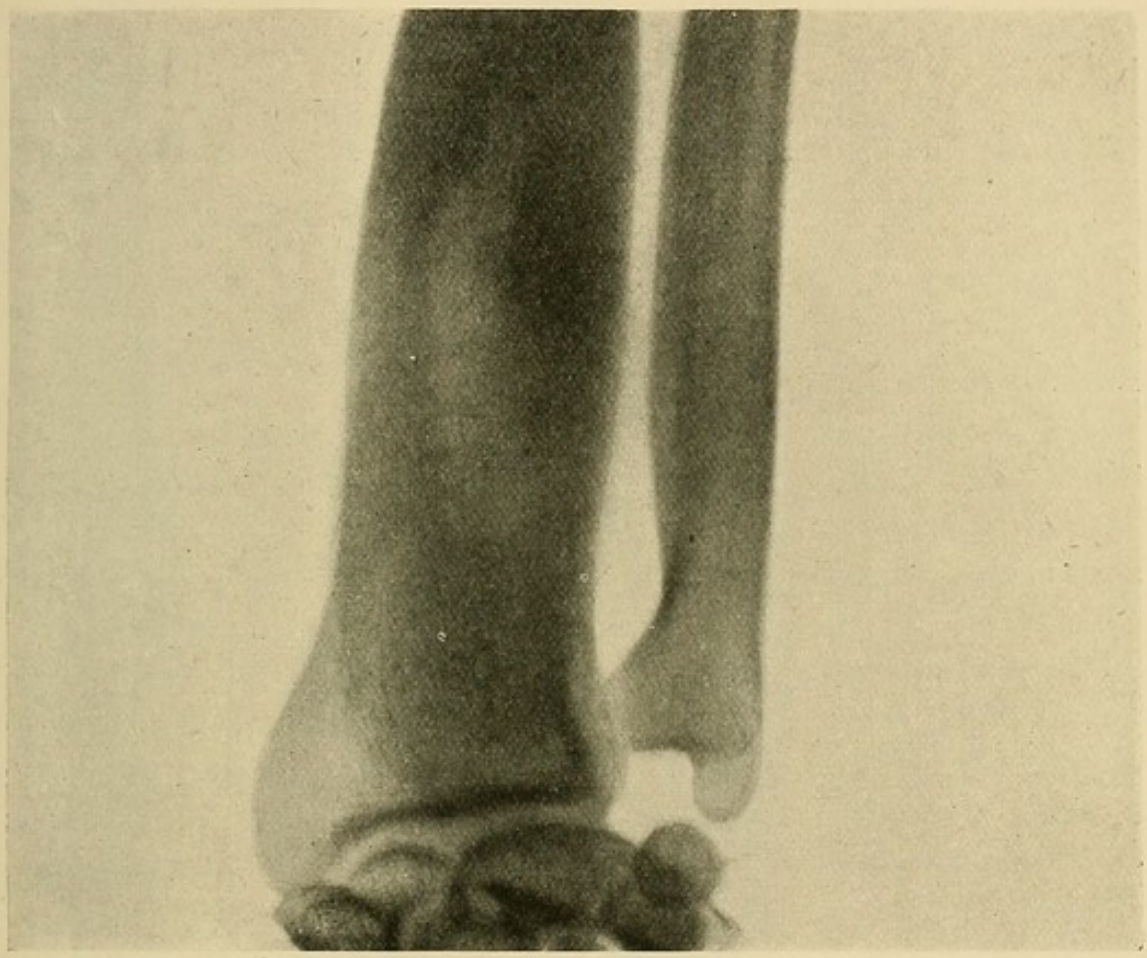


FIG. 144.—THICKENING OF LOWER END OF RADIUS, WITH ABSCESS CAVITY
Mr. Robert Jones's case. Dr. Morgan.

right arm in lifting a box. Within the next ten years he sustained no less than twenty-two fractures. At the age of thirty he appeared to have recovered, but with great deformity of body and limbs, due to frequent fractures and muscular atrophy. Dr. Biggs has appended a valuable article on the condition.

Osteopsathyrosis is essentially a condition of microscopic or

* *University of Pennsylvania Bulletin*, vol. xv., March, 1902, to February, 1903, Philadelphia, 1903.

macroscopic osteoporosis producing a fragility of osseous structures, resulting in multiple fractures. The bones are not soft and pliable, as in rickets and osteomalacia, but are brittle, and instead of bending and yielding to pressure, they break under trifling stress. In the idiopathic form of the disease the primary underlying factor appears to be uniform widespread fragility of bone—*i.e.*, apart from secondary fragility associated with definite general or local con-

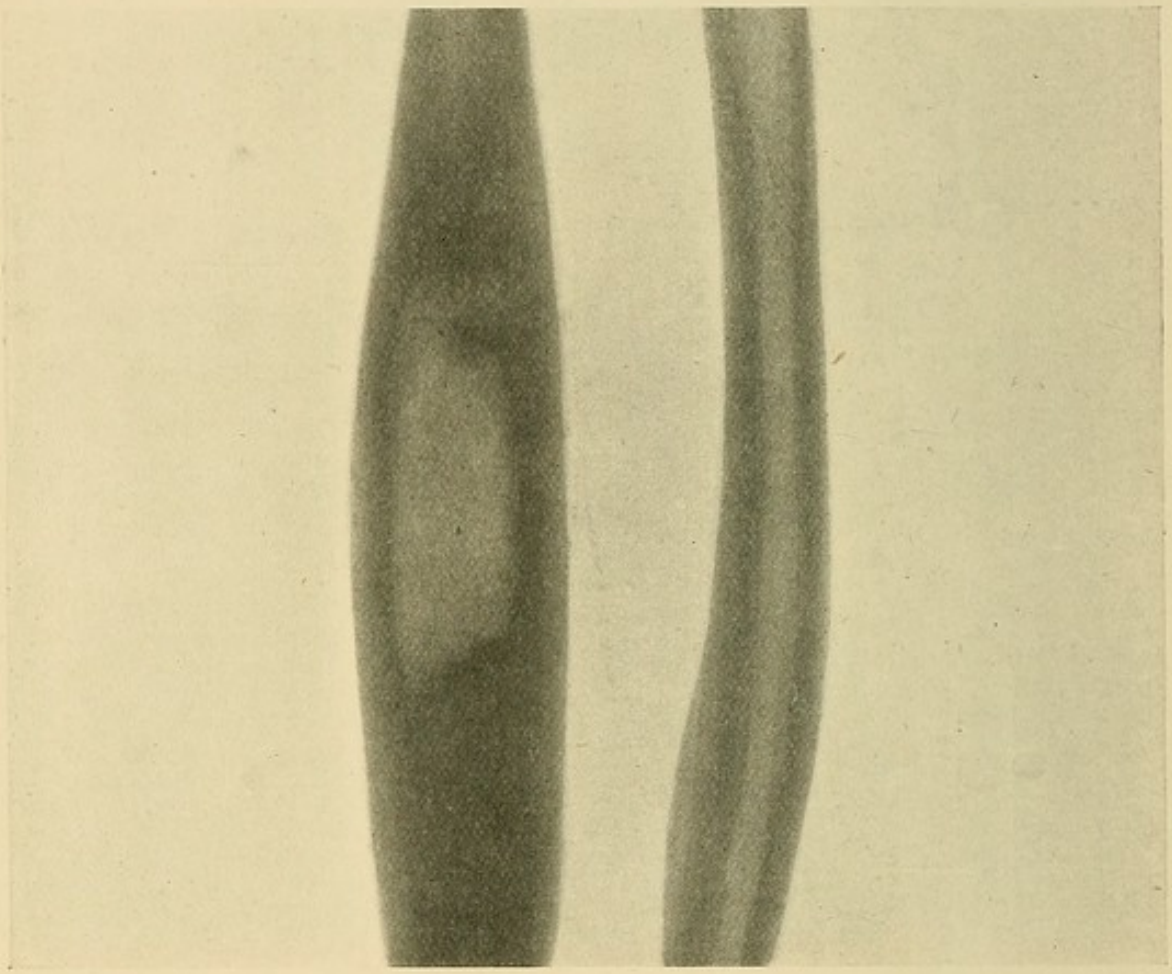


FIG. 145.—SMALL CYST OF ULNA IN A WOMAN AGED EIGHTEEN YEARS.
Mr. Robert Jones's case. Dr. Morgan.

dition as osteomalacia, rickets, tabes dorsalis, carcinoma, syphilis, and osteomyelitis.

The commonest site of fracture is the femur, and next in order of frequency the leg, arm, and forearm. Early union is the rule. One peculiarity is the absence of permanent callus at the site of fracture. In bones often broken the resulting deformity is of an extreme, and sometimes of a grotesque, kind. Muscular atrophy, due to enforced disease, is common.

The disease has a medico-legal interest, inasmuch as it may explain the occurrence of fractures in personal encounters where the force exerted was inadequate to account for such an injury. It has been frequently noted among the insane, and may result from the mildest form of restraint among such patients. Under such circumstances, it is easy to see how an unfounded charge might be brought against the attendants.

Bone Sarcoma.

Dr. Richardson, of Philadelphia, says that by the aid of the fluoroscope he has been able to watch the growth of an osteo-sarcoma of the radius from day to day. His case is thus described:

'General W——, aged fifty-nine, had suffered for twelve months from a painful swelling of the right wrist. By means of the fluoroscope the ulna was seen to be intact, the radius to terminate abruptly in the faint shadow of a carpal tumour. A thin shell of the radius could be seen remaining. The diagnosis of osteosarcoma of the radius, made from the history of the case and from inspection and digital examination, was practically proved by the fluoroscope and the skiagram. A previous consultant had assured this patient that the tumour was an aneurism of the radial artery. In a second skiagram, taken a month later, the shell of bone had entirely disappeared—a fact that demonstrated the bony origin of the tumour and the rapidity of its extension. The arm was amputated, and the disease proved to be an osteosarcoma of the radius.'*

A sarcoma of the os calcis has been described by Professor Hector C. Cameron† in a woman of sixty-eight, who had suffered for twelve months from pain in the ankle. A radiogram showed bulging on the plantar aspect of the os calcis. The lower half of the bone gave a much lighter shadow than the upper half and the neighbouring bones. After operation, microscopic examination showed the tumour to be a round-celled sarcoma with alveolar arrangement in meshes of delicate fibro-cellular tissue.

The diagnosis between benign osseous cyst and malignant osteo-sarcoma is often one of no little difficulty. Both are slow and painless in their onset; they occur in young people, often following an

* *New York Medical News*, December 19, 1896.

† *Glasgow Medical Journal*, May, 1900, p. 386.

injury, and present more or less identical physical signs. It has been pointed out by Dr. Carl Beck,* however, that in osteosarcoma the outlines of the bone always appear more or less abnormal and indefinite, some areas even appearing entirely translucent; while in osseous cyst the cortex appears thin and narrow, but well marked and regular. The fluid portion of the bone is entirely translucent, the light shade showing the same regularity. The adjacent epiphyses are normal. It is especially the regularity of the texture of the walls of the cavity as they appear on the skiagram which seems to me to be the characteristic feature of osseous cyst in contradistinction to the irregular texture of osteosarcoma.'

The same observer has recorded a case in which the Röntgen rays established a diagnosis of femoral aneurism which showed no pulsation on account of its extremely thick walls, and had been previously mistaken for osteosarcoma.

The accompanying figure is from a case of sarcoma of the radius under Mr. Marmaduke Sheild. It shows excellently the radiographic appearance typical of that condition, and is here reproduced by courtesy of Mr. F. T. Addyman from his book on 'Practical *X*-ray Work' (see Fig. 146).

Mr. Robert Jones † has reported a case of sarcoma of the upper third of the fibula in a girl of eight. The skiagraph showed the growth to be well localised, and it was accordingly treated by excision. In this case the *x*-ray picture was accurate enough to indicate the nature and even the steps of the operation.

Leprosy.

Mr. E. H. Howlett,‡ surgeon to the Hull Royal Infirmary, has reported a case of anæsthetic leprosy in a West Indian, aged twenty-one. His skin presented extensive areas of leucoderma. The right thigh and leg were in a state of elephantiasis, and there were perforating ulcers on the soles of the feet. The radiograph showed considerable destructive changes, chiefly affecting the terminal phalanges (see Figs. 153, 154).

* *American Journal*, June, 1901, p. 666.

† *Liverpool Medico-Chirurgical Journal*, January, 1904, p. 843.

‡ *Quarterly Medical Journal*, February, 1902, p. 142.

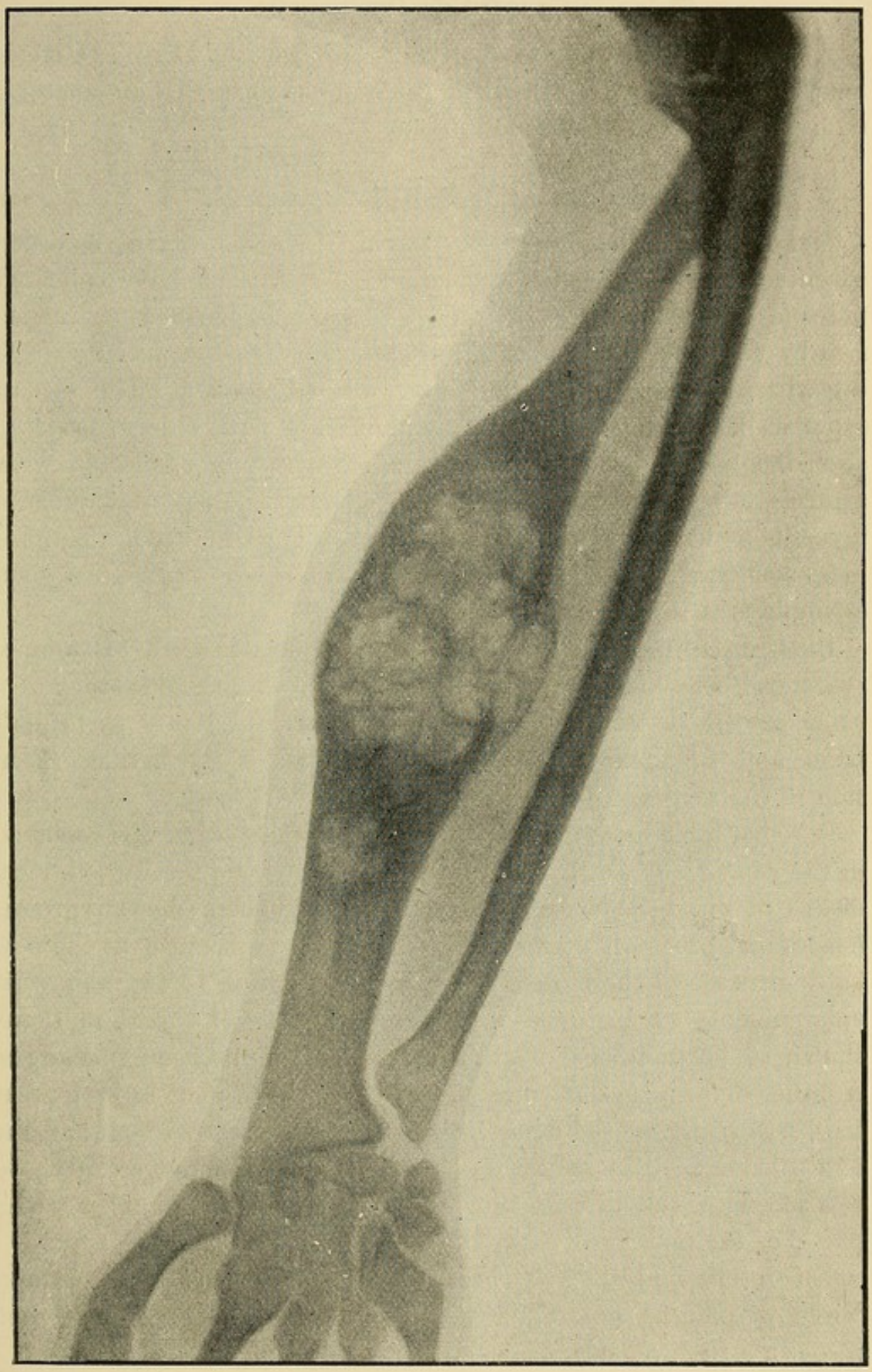


FIG. 146.—SARCOMA OF RADIUS.
From Addyman's 'Practical *X*-ray Work.'

Rarefying Osteitis.

A beautiful plate of this condition is published by Dr. W. D. Heidman,* of Ann Arbour, Michigan (January, 1905). Unfortunately, no history of the case was obtainable.

Traumatic Myositis Ossificans.

Mr. Robert Jones and Dr. David Morgan † have recorded seventeen cases, and, with the help of Dr. Aitken, have collected notes of 250 other cases. Ordinary myositis ossificans is characterised by the progressive ossification of various muscles, usually starting with the trapezii, latissimi dorsi, and rhomboids. The second concerns certain groups of overtaxed muscles, as in riders', fencers', and dancers' bones. The traumatic variety is connected with injuries, especially with dislocations. The pathology of traumatic myositis ossificans is not yet worked out. The condition is perhaps most commonly met with in injuries about the elbow-joint. A good example is that shown in Fig. 147.

Ossifications of various kinds can be detected. Examples are those occasionally met with in muscle, as the adductors of a rider or the deltoids of a soldier, known respectively as 'rider's bone' and the 'drill-bone.' Another instance is the ossified insertion of the rectus femoris muscle in Charcot's disease.

A remarkable case of progressive myositis ossificans was reported in the *Lancet* ‡ by Dr. R. Crawfurd and Mr. Harry Lockwood. By means of radiograms, a tendency to overgrowth of normal prominences and processes was noted—a point of importance, as the new bony growths in the muscle are always in relation to the abnormal enlargements of protuberances. Microdactyly of the thumb was shown to be due to synostosis of the first and second phalanges. Another deformity, described as hallux valgus, present in both great toes, was really caused by synostosis of the metacarpal bone and the first phalanx. The latter deformity has been noted so often in relation with the disease that the authors regard it as part and parcel of the malady.

An interesting case has been published by Dr. de la Camp.§ Virchow pointed out that the ossification in this patient took place in structures near bones rather than in muscles.

* *Archives of the Röntgen Ray*, No. 54. † *Ibid.*, No. 57 *et seq.*

‡ *Lancet*, April 15, 1899.

§ *Fortschritte auf dem Gebiete der Röntgenstrahlen*, B. I., 1897-1898.

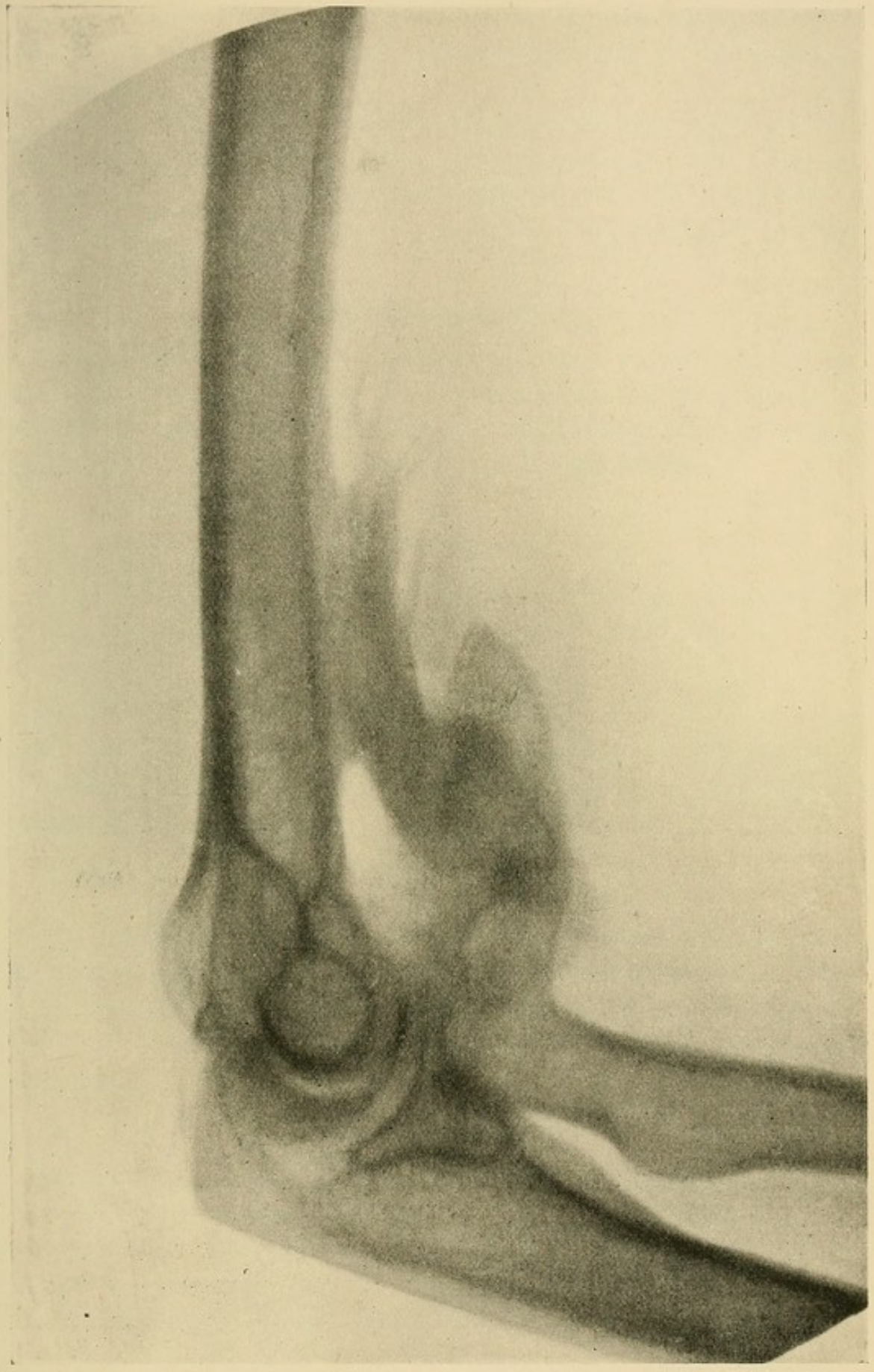


FIG. 147.—MYOSITIS OSSIFICANS FOLLOWING FRACTURE OF ELBOW.
Mr. Robert Jones's case. Radiographed by Dr. Morgan.

An admirable review of the literature on this interesting subject, with full bibliography, has been given by Lydia M. de Witt, M.D., of Michigan.*

Dr. Léon Cahier,† of Val-de-Grâce, has reported the case of a man, aged twenty-three, in whom a hard tumour developed in the anterior part of the right brachialis anticus shortly after a kick from a horse. The skiagraph showed a light shadow in the substance of the muscle.

Osteosclerosis.

General thickening and hardening of bone is well shown in Fig. 148. The case was one of tubercular disease of the femur in a boy of ten years, under the care of Mr. Robert Jones. In the centre of the sclerosed bone may be seen a small abscess.

Leontiasis Ossium.

A beautiful illustration of the hypertrophic bone changes in leontiasis, lent by Mr. Robert Jones, is reproduced in Fig. 149.

Osteitis Deformans.

To the same surgeon the author is indebted for the full-page illustration (Fig. 150), showing the hyperplasia of bone and deformity of osteitis deformans.

Cyst around Bone.

The condition shown in Fig. 151 is of value because it illustrates a periosteum diagnosis—namely, the destruction between new growths of periosteum bone or of surrounding soft tissue and simple cyst. The chief point to be noted is the clear and unaltered margins of the bone.

Periosteal Sarcoma.

The foregoing condition of cyst around femur should be carefully compared with the figure (Fig. 152) of periosteal sarcoma from a case also under Mr. Robert Jones's care. It will be seen that the outlines of the bone are blurred and irregular, points of value in determining a diagnosis that is difficult, at any rate in its early stages.

* *American Journal of Medical Sciences*, September, 1900, p. 295.

† *Revue de Chirurgie*, March 10, 1904, p. 356.

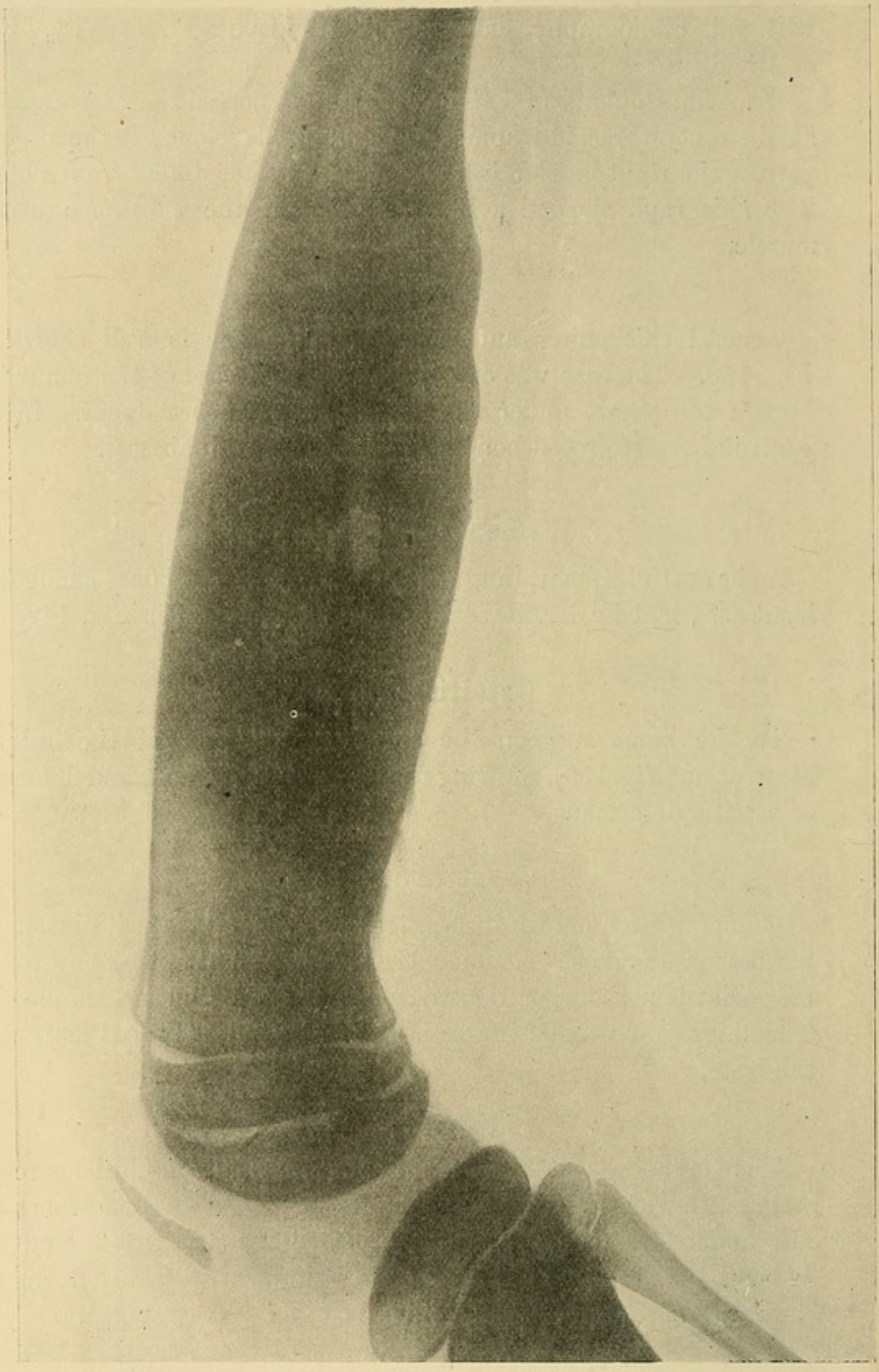


FIG. 148.—OSTEOSCLEROSIS OF FEMUR IN BOY OF TEN YEARS, WITH ABSCESS CAVITY (TUBERCULAR).

Mr. Robert Jones's case. Radiographed by Dr. Morgan.

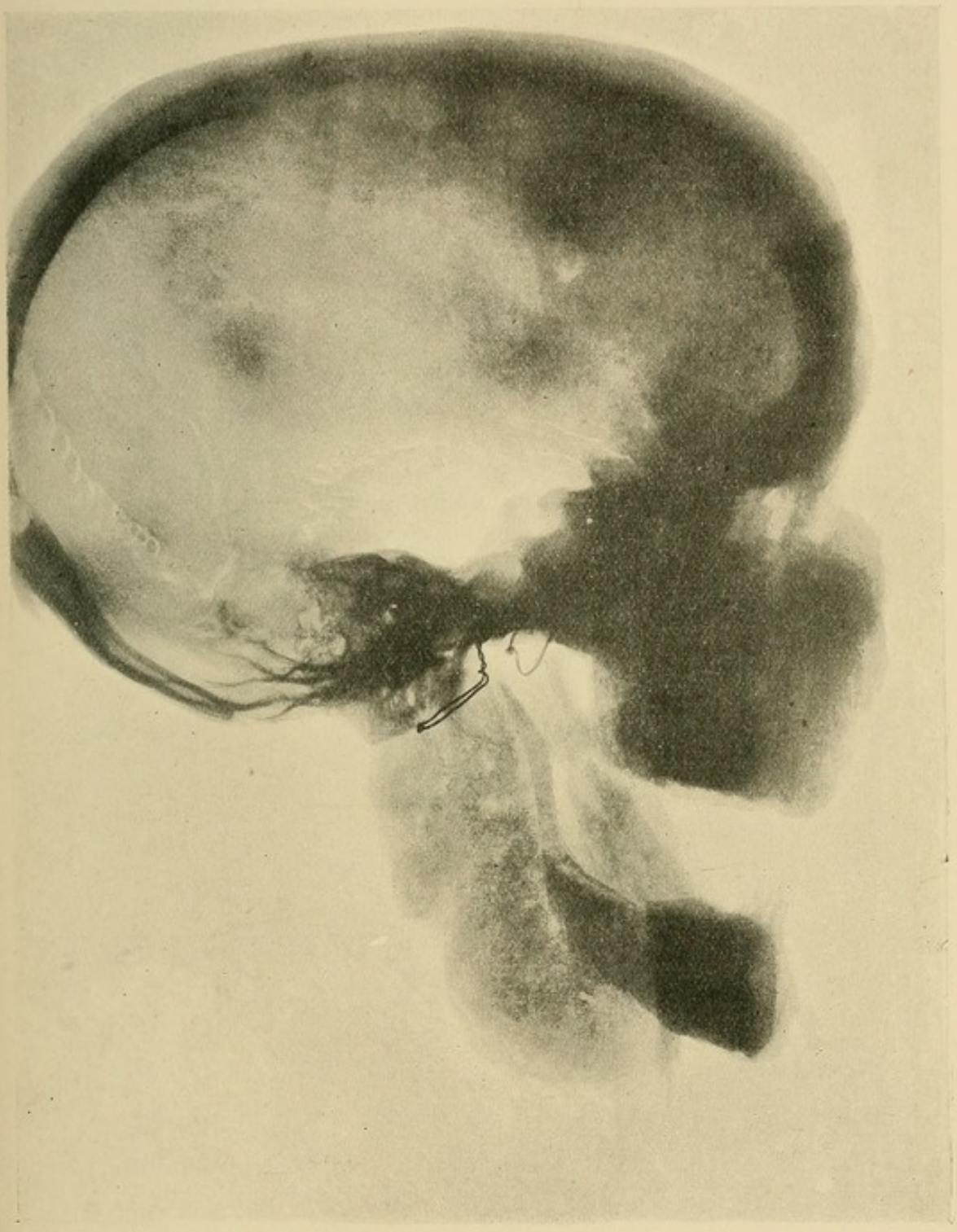


FIG. 149.—LEONTIASIS OSSIUM FROM HALF A SKULL.
Mr. Robert Jones's case. Dr. Morgan.

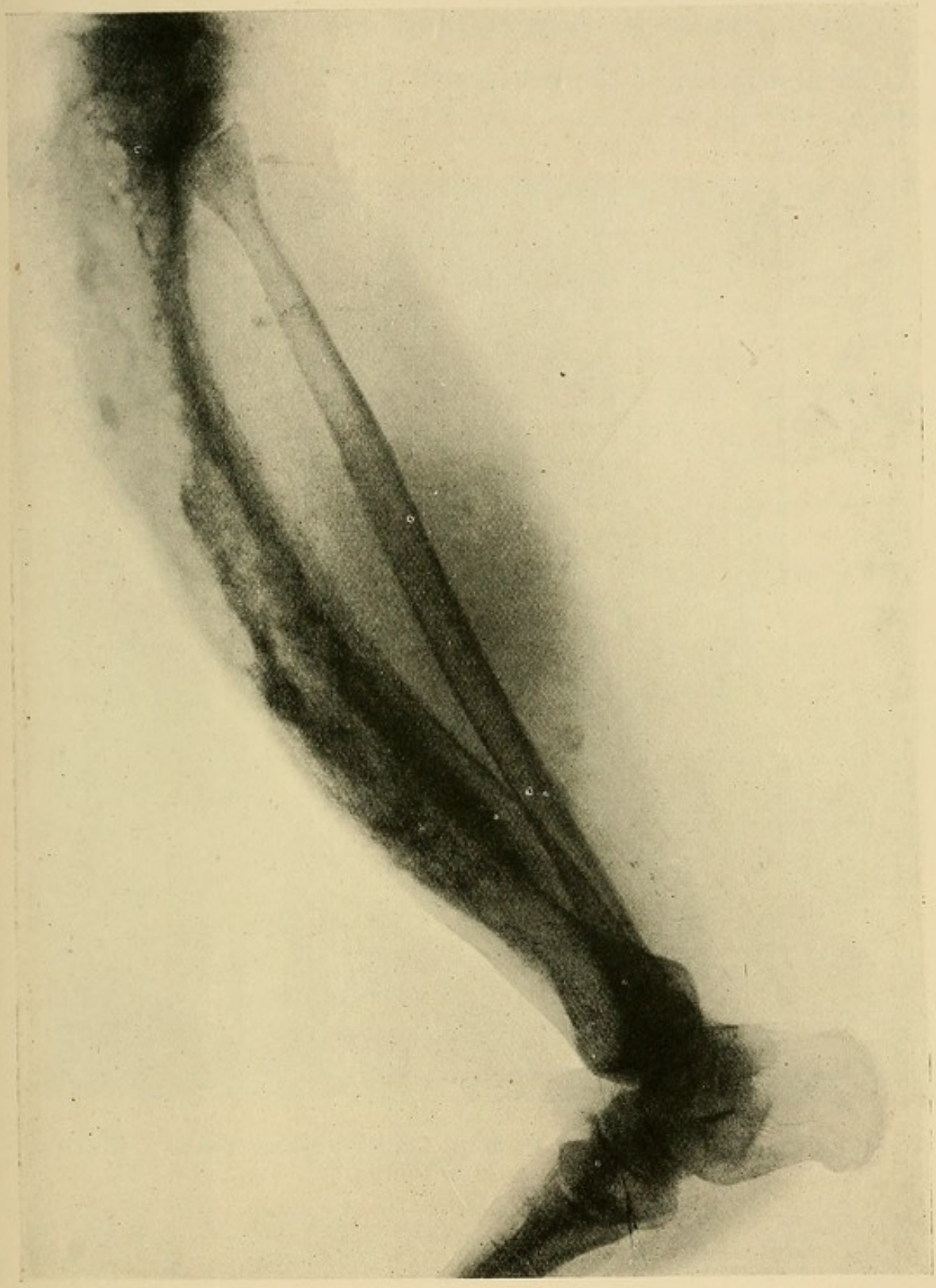


FIG. 150.—OSTEITIS DEFORMANS OF LEFT LEG IN A WOMAN OF SIXTY-SIX YEARS.
Mr. Robert Jones's case. Dr. Morgan.

Bones in Leprosy and Syphilis.

As an illustration of the unexpected way in which the *x*-rays come to the aid of science may be taken the researches of

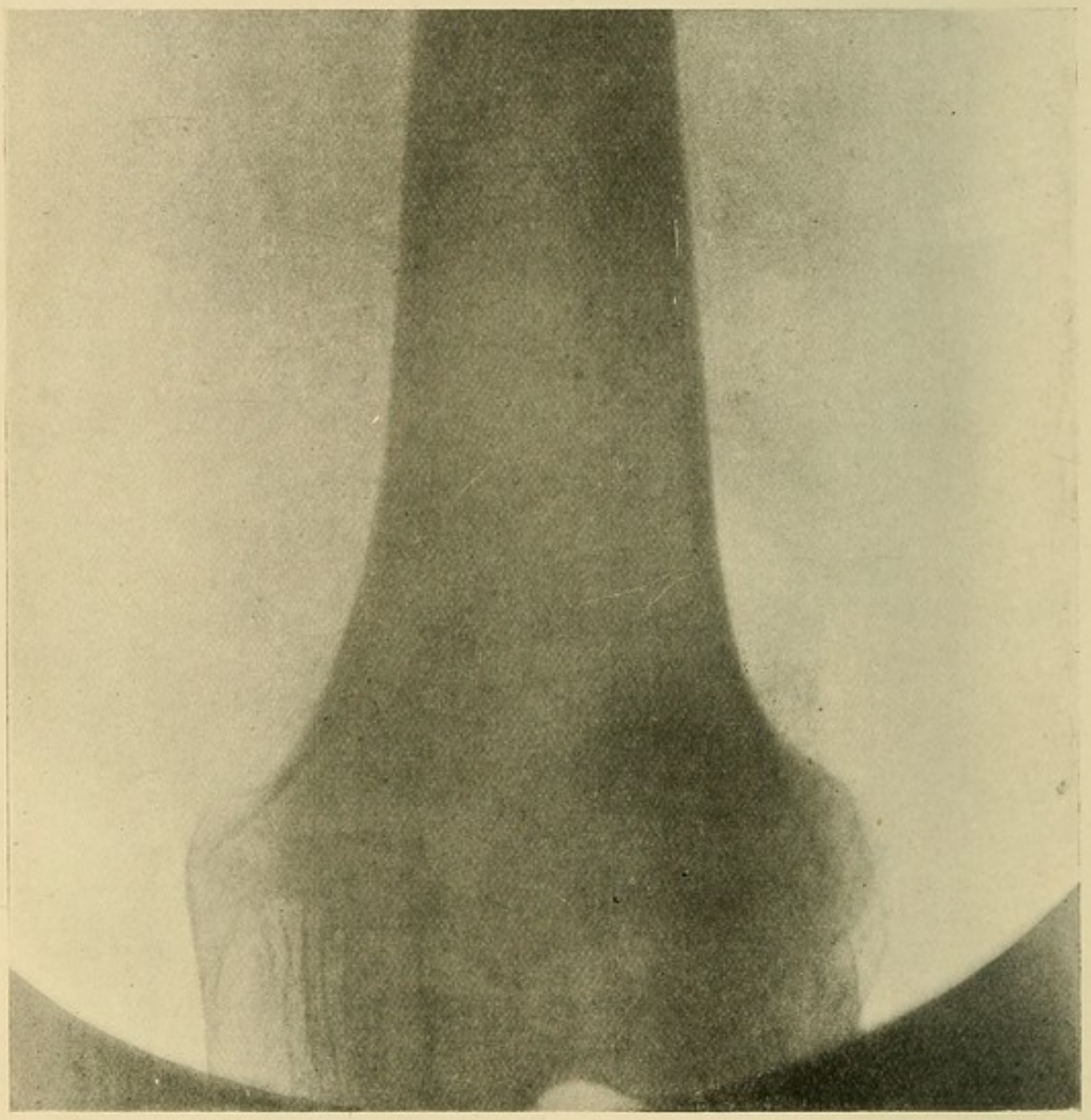


FIG. 151.—CYST AROUND FEMUR IN MAN AGED SIXTY-SIX YEARS. (NOTE CLEAR MARGIN OF FEMUR.)
Mr. Robert Jones's case. Dr. Morgan.

Dr. Ashmead, of New York.* For a long time there has been a dispute whether certain bone changes observed in Peruvian mummies were due to a pre-Columbian leprosy, the existence of

* *The Canadian Journal of Medicine and Surgery*, vol. v., No. 3, March, 1899.

which he denied. In the absence of radiographic evidence of absorption of the bones of the hand and falling in of the nasal bones, and of other bone changes connected with leprosy, he has confirmed the view already arrived at from other directions that there was no pre-Columbian leprosy in America. The conclusions

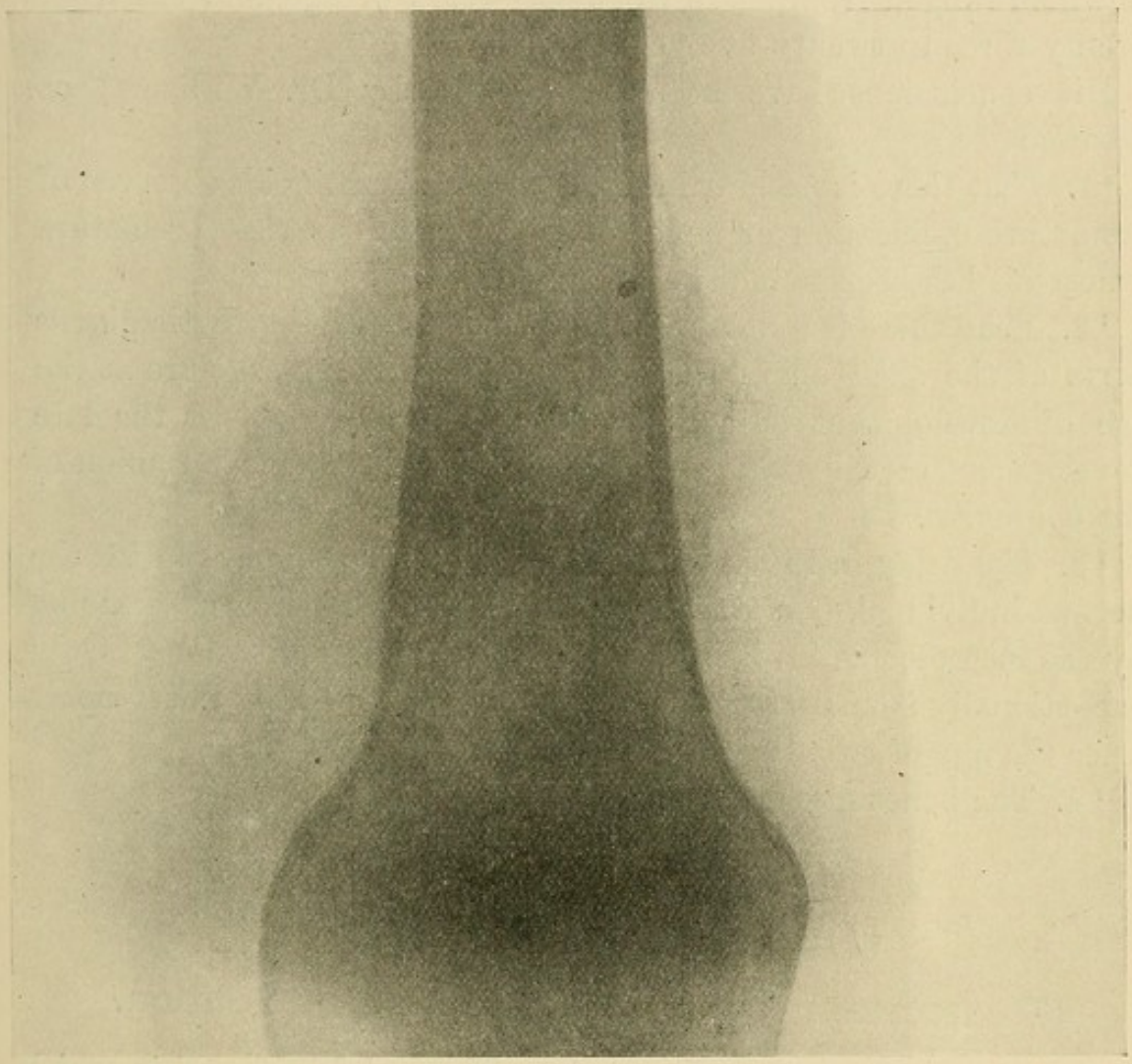


FIG. 152.—PERIOSTEAL SARCOMA (SMALL ROUND-CELLED) IN FEMUR OF WOMAN AGED TWENTY-FOUR YEARS.

Mr. Robert Jones's case. Dr. Morgan.

of this most learned investigation, however, appear to point to the existence of pre-Columbian syphilis. The bone changes in leprosy are shown in two radiograms, kindly furnished by Mr. E. H. Howlett, of Hull.

The Bones in Cretinism.

A full description of a cretin girl four years old has been published by Hofmeister. The bones were ill-developed and the

epiphyses wanting except in a few instances, where their presence was indicated by faint centres of ossification.*

A more general investigation of the development of bones in cretins and in cretinoids has been made by Robert von Wyss.† His observations were conducted upon thirty patients, twenty-four of whom ranged from seven to twenty years of age, and six from twenty-three to twenty-five years of age.

His conclusions have been summarized by Dr. Williams‡ as follows :

'1. That there is no hint in the cretins and cretinoids observed of premature ossification or synostosis' (he mentions that premature synostosis has been taught for forty years).

'2. That there is a delay in the ossification of the cartilaginous parts of the skeleton in the cretins and cretinoids who are at the age of development or a little older only, as shown by the late development of the centres of ossification and the delayed union of the epiphyses.

'3. The delay in the process of ossification, as compared with the normal individual, is of a few years' duration only, as a rule, judging by the macroscopic investigation and the *x*-ray examinations. Only exceptionally is an abnormal condition to be found in this respect after the age of twenty-five.

'4. The bones of the hands are the latest to ossify.'

(*f*) OTHER SURGICAL POINTS.

To ascertain Results of Osteoplastic Operation.

An interesting case is recorded by Howard Lillienthal in which both the desirability and the results of a bone plastic operation were plainly indicated by the rays. His patient had lost the use of a leg after a severe injury. A radiograph showed considerable loss of substance of the body of the tibia. To remedy this state of things, the operation of tibio-fibular osteoplasty was performed by cutting through the fibula, and bending it over to lie obliquely in the long axis of the gap in the shin-bone. The successful result was proved

* *Fortschritte auf dem Gebiete der Röntgenstrahlen*, 1897-1898, pp. 4-12.

† *Ibid.*, B. III., 1899-1900.

‡ 'Röntgen Rays,' F. H. Williams, M.D., second edition, p. 462, Macmillan, New York, 1902.

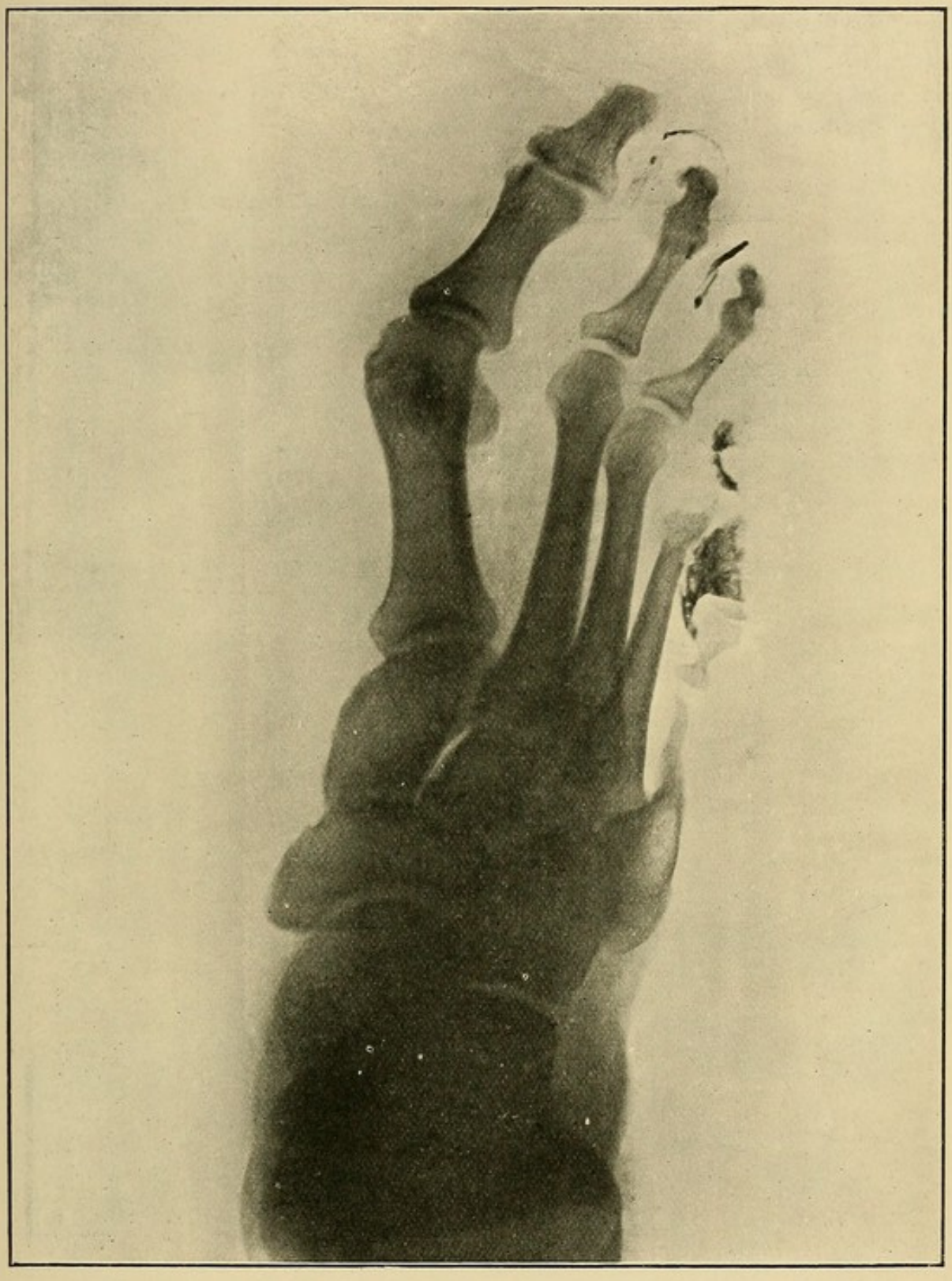


FIG. 155.—FOOT IN LEPROSY SHOWING BONE ABSORPTION (SOME OF THE MARKINGS DUE TO AN OPAQUE DRESSING).

E. H. Howlett, F.R.C.S.

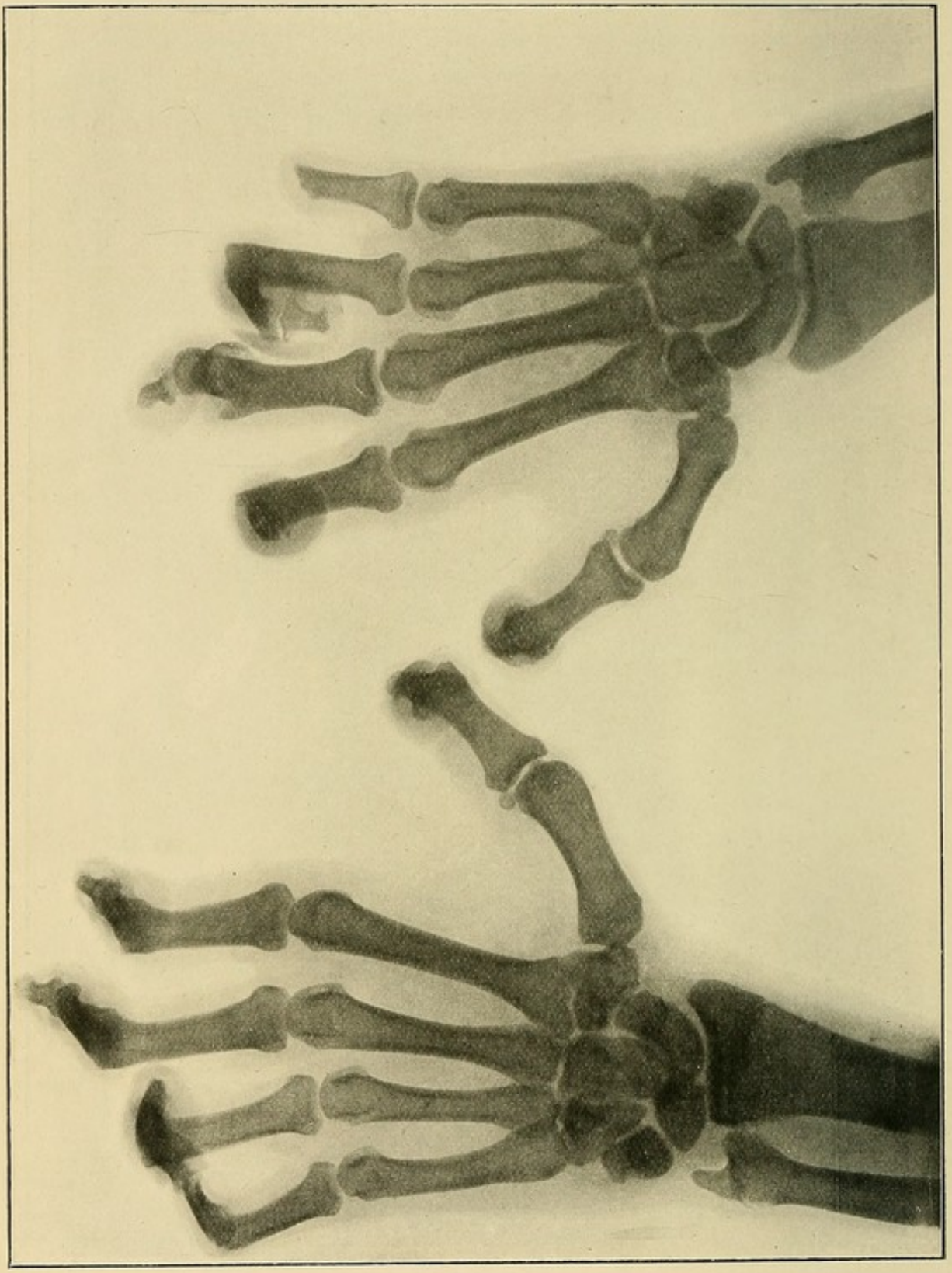


FIG. 154.—HANDS IN LEPROSY.
E. H. Howlett, F.R.C.S.

some time afterwards by a Röntgen-ray photograph, which revealed bony filling of the gap and restoration of the line of the fibula, with union of the two bones by an osseous bridge.

An important point is that when a piece of rabbit or other bone has been transplanted, the surgeon can ascertain whether it has or has not become established in its new position.

Joint Affections in Locomotor Ataxy.

The pathology of this condition has been illustrated in a case reported by M. E. Dupré and A. Devaux.*

A man aged fifty-four, under treatment for well-marked locomotor ataxy. In 1890 lightning pains occurred, varied by painless enlargement of both knees in 1897. The radiogram showed that the articular enlargement and deformity were due, not so much to lesion of the articular extremity of the bone as to changes in their relations to each other, to synovial effusion, and to osteofibrous growths within the capsules of the joint. The femoral condyles of the knee-caps were normal, and the head of the left tibia alone was enlarged. On both sides the knee-cap was displaced forward and the femur backwards.†

Charcot's Joint.

Some of the typical changes of a 'Charcot' joint are shown in Fig. 155, kindly furnished by Mr. Robert Jones. The chief characteristics of this tabetic affection, it need hardly be said, are effusion, destruction of cartilages, atrophy, rarefaction of bone sometimes leading to fractures, and irregular outgrowths of bone in or near the joint. These changes, occurring singly or combined, constitute the arthropathy and the osteo-arthropathy of the tabetic joint.

Reproduction of Bone.

An interesting case of reproduction of the diaphysis of the tibia after removal for acute infective periostitis and osteomyelitis has been published by Mr. R. J. Pye-Smith.‡ The patient was a girl of nine. The main part of the shaft of the tibia was removed from its

* *Nouvelle Iconographie de la Salpêtrière*, September to October, p. 498.

† For illustration, see *Medical Review*, vol. iii., No. 26, November, 1900, p. 668.

‡ *Quarterly Medical Journal*, May, 1901, p. 262.

loosened periosteum, and the resulting cavity stuffed with gauze, while the fibula acted as a splint. The tibia was almost perfectly reproduced. (See Fig. 156, by courtesy of the *Quarterly Medical Journal.*)

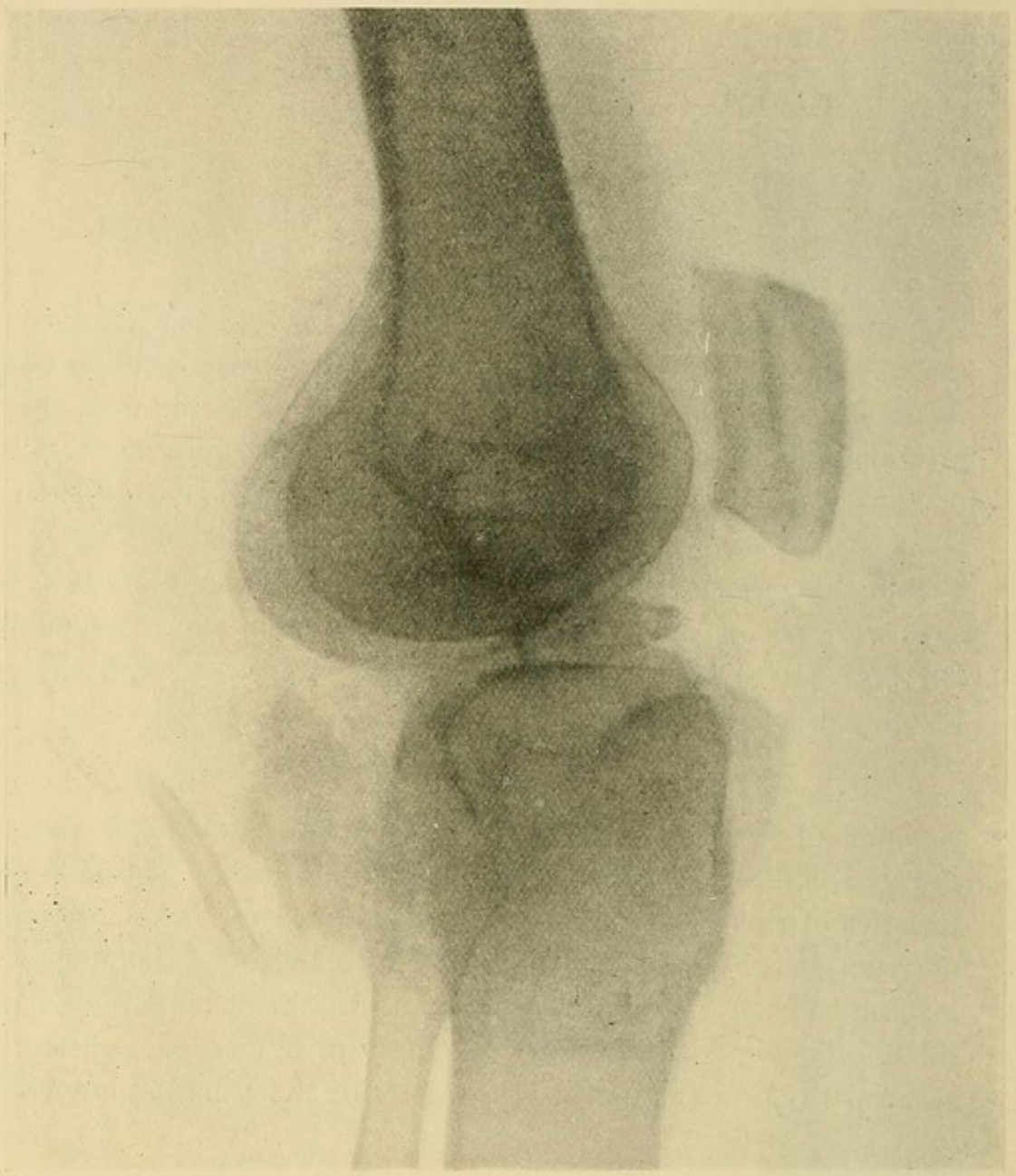


FIG. 155.—CHARCOT KNEE IN A WOMAN AGED FORTY-THREE YEARS.
Mr. Robert Jones's case. Dr. Morgan.

Iodoform Stopping for Bone Cavities.

A most interesting description of the filling up of the cavity in a bone after removal of a sequestrum or of carious matter has been devised by N. Hackmann.* He uses the iodoform stopping of Pro-

* *Wien. Klin. Woch.*, May 30, 1901, p. 537.

fessor von Mosetig-Moothof, which adapts itself to every crevice, and is at the same time absorbable and aseptic. It is made of iodoform 30 to 60, olei sesami 20, and cetacei 40 parts. For

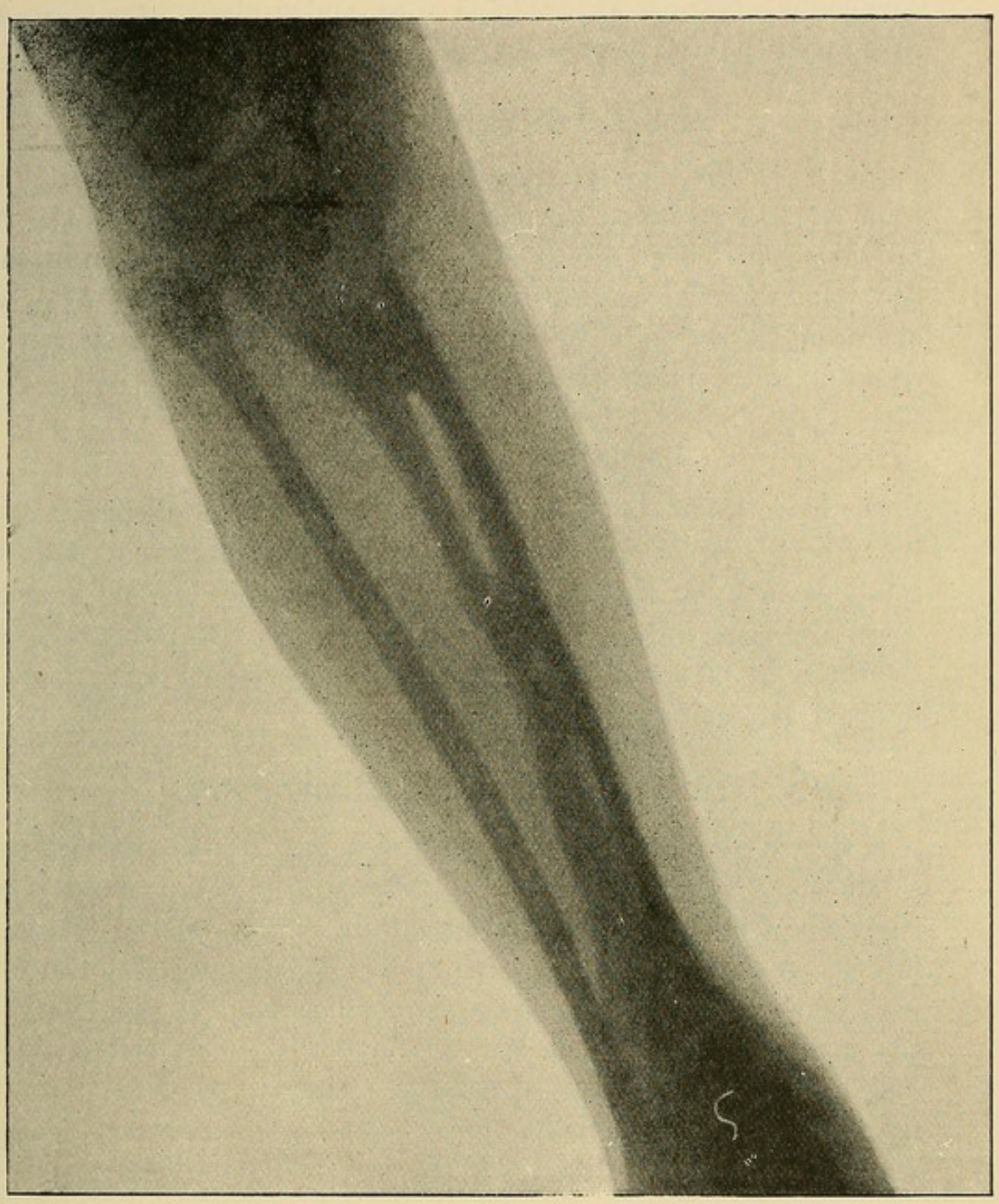


FIG. 156.—BONE REPRODUCTION.

Mr. Pye-Smith's case.

details of the method, the reader is referred either to the original article or to an abstract in the *Medical Review* for September, 1901, in which some interesting radiograms are reproduced, showing the

various stages of filling and absorption. The method is applicable to cavities in bone, whether from osteomyelitis, necrosis, or tuberculous caries, provided that they are previously rendered aseptic. The composition used is made so as to render absorption slow, and thus avoid the risk of iodoform-poisoning.

Excision of Semilunar Cartilage.

Mr. F. D. Bird has published a case of a boy from whose knee-joint he had removed the internal semilunar cartilage. The boy previously had been almost entirely crippled from the condition of the joint with its accompanying attacks of synovitis. After the operation the action of the knee-joint became perfect, and the boy could not only follow his occupation, but even play football.

Loose Bodies in Knee-Joint.

Dr. E. A. Codman,* of Boston, finds that torn or displaced semilunar cartilages cannot be discerned by the *x*-rays, but that the small osteophytic fragments which so frequently become detached as a result of injury are, of course, visible. A radiogram may therefore be of some service previous to operating upon cases of internal derangement of the knee-joint.

Loose Cartilages in Elbow-Joint.

Major W. B. Nisbet† has recorded a case of this rare surgical condition. The patient was a private, aged thirty-four, whose right elbow became swollen and painful. There was no history of injury. A skiagram showed two rounded bodies lying in the anterior part of the joint, just above the coronoid process of the ulna. At the operation, which had become imperative, two bodies slipped out, each about the size of a bean. These proved to consist of ossifying cartilage. Further *x*-ray examination revealed the presence of a similar third body, which was subsequently removed.

Rupture of Tendons.

In some cases the rupture of tendons can be demonstrated by means of the Röntgen rays. This is especially the case with the tendo Achillis, the gap in which can be readily seen and measured

* *Boston Medical and Surgical Journal*, October 15, 1903, p. 427.

† *The Australasian Medical Gazette*, December 21, 1903, p. 553.

from the radiogram. Mr. Lynn Thomas ruptured that particular tendon on the voyage out to South Africa in March, 1900. He has informed the writer that he followed up the changes radiographically at every stage, from the receipt of the injury until complete cure. In June, 1901, the united tendon was 1 centimetre thicker and wider than that on the uninjured side.

Healing of Wounds.

Dr. D. Berry Hart* has recorded a case of callous abdominal sinus, which healed with marvellous rapidity after the application of *x*-rays. In one instance the sinus followed an exploratory operation in the right iliac fossa, and exposure to the rays effected a speedy cicatrization after weeks of plugging with gauze had failed.

Operation with Screen.

White has suggested the combined use of instruments, as the curved forceps, with the fluorescent screen. A similar suggestion has been made by Mr. T. L. Gillanders, M.B. After failure to find a bullet in a hand where it had been shown by the rays, he removed it by observing its relative position to the bullet forceps upon the fluorescent screen. The first negative result was due to the fact that the bullet had become flattened against the bone, and was bound down tightly by the powerful flexor tendon. Mr. C. G. Burton, of the North-Eastern Hospital for Children, London, has recorded another interesting case of a coin thus removed.†

Dr. G. W. Dunn‡ (Jarrow-on-Tyne), guided by a screen shadow, passed a small hook around and extracted a needle buried in foot. He had failed previously to find the foreign body by operation.

Hysterical Hip (Author's Case).

'The following case is of interest as showing an exaggerated instance of hysterical hip, and of the value of the negative evidence at times afforded by the Röntgen rays. The patient was wearing a high-heeled shoe, and walked lamely, but the Röntgen photograph revealed a normal hip-joint. Further examination showed that the shortening was apparent only, and there was no pain or tenderness

* *British Medical Journal*, May 31, 1902, p. 1330.
† *Ibid.*, April 1, 1899.
‡ *Lancet*, vol. i., 1899, p. 163.

in the joint, no prominence of the trochanter, and no flattening or widening of the buttock. It appears that two years previously she felt pain at times in the right side from the hip downwards as far as the knee. She went to a medical man, who treated her for hip-joint disease, and the heel of her boot was built up from time to time to compensate for the supposed shortening. The patient came of a markedly phthisical family, and was of a neurotic temperament.'

Ossifications of the costal cartilages are shown in old persons. One remarkable instance of premature ossification of the kind in a woman of twenty has been reported as disclosed by the rays.

Calcification of arteries has been shown in the neck and limbs. Atheromatous changes have also been frequently noted in the heart and larger deep bloodvessels, and can now be demonstrated in small arteries and in comparatively early stages.

The subperiosteal enlargements met with after injury in strumous subjects are well shown by the Röntgen rays. In one such case of 'strumous dactylitis' a boy of fourteen suffered from a swollen finger after a fall some weeks previously. A photograph taken by the writer revealed a considerable periosteal enlargement of the first phalanx of the third finger. The effused material, however, was not opaque as a whole, but showed a few granules, apparently of commencing calcification or ossification. The lower epiphysis appeared to be partly obliterated, probably owing to the tilting up of the inter-epiphyseal cartilage by the swelling of the finger, whereby the direct passage of the rays was prevented.

(*g*) Action of the Rays upon Micro-organisms.

It is still open to question whether the Röntgen, or, rather, the 'focus-tube' rays exercise any germicidal effect upon micro-organisms, although it seems to be more than likely that they more or less inhibit bacterial growth. Numerous experiments have been made. Thus, Professor W. W. Keen, of Philadelphia, reports* of pink streptococcus, anthrax, *Micrococcus prodigiosus*, *Micrococcus cereus flavus*, *Sarcina aurantiaca*, yellow sarcina, tubercle bacilli, that after exposures, first of half an hour, and then twice for fifteen minutes, neither lethal nor inhibitory effects were exerted upon the cultures.

* *American Journal of Medical Sciences*, March, 1896.

These experiments confirmed conclusions previously published by Dr. Davis in the same journal.

Berton * exposed bouillon cultures of the diphtheria bacillus to the rays for periods of sixteen, thirty-two, and sixty-four hours, but in no instance did he note any injury to the vitality of the organisms.

J. Brunton Blakie, M.B.,† as the result of numerous experiments carried out at the University of Edinburgh, concluded that the Röntgen rays have no visible influence on the growth of cultures of the tubercle bacillus, and that the delicate chemical structure of diphtheria toxine, like the delicate chemical structure of the retina, is not affected by their vibrations. Similar conclusions were arrived at by Dr. Francis Pott with regard to the tubercle bacillus, which were unaffected by exposures of eleven hours' duration.

Different investigators have arrived at conflicting results. Thus, Dr Rieder has ‡ reported an inhibitive bactericidal action of the *x*-rays upon cultures of diphtheria and tubercle bacilli, pyogenic cocci, and so on, with an exposure of one to three hours. He used various media on culture-plates beneath a sheet of lead with a round hole cut in it, and so arranged that the rays of a focus-tube fell on one portion of the culture. Ordinary light was excluded by covering the aperture in the lead with black paper. He found that the various organisms flourished upon that part of the plate sheltered from the rays by the opaque leaden screen, while on the exposed part beneath the circular aperture they were either absent or feebly developed. From the fact that the gelatin was not liquefied, he thinks that heat was not the inhibitive agent ; the chemical nature of the medium was not altered, as shown by the fact that cultures subsequently grew thereon ; and ordinary light had been excluded by the black paper. His experiments are suggestive, and point to the possibility of inhibition of bacterial growth by the focus-tube rays that are able to penetrate black paper, or to electrical influences.

Boromo § concluded that the rays are negative as regards chromogenic bacilli ; that they quicken the sporulation of *B. subtilis* and retard that of *B. anthracis*. At the fourth Congress for the

* *Bull. Gén. de Thérap.*, November 8, 1896.

† *Scottish Medical and Surgical Journal*, May, 1897.

‡ *Münch. Med. Woch.*, 1898, No. 4, p. 101.

§ *Bollett. della Soc. Lanc. degli Osp. di Roma*, xvii., par. i., p. 287.

Study of Tuberculosis, held in Paris in the autumn of 1898, the general opinion was that the rays possessed neither inhibitive nor destructive action upon micro-organisms.

Drs. Norris Wolfenden and Forbes Ross made a series of experiments with *Bacillus prodigiosus*. They found that up to the fifth generation the result of exposure of a culture for one hour to the *x*-rays was to increase the pigment-forming power, and to induce an exuberant growth.

Rieder found that cholera vibriones were killed by an exposure of two hours. Development of *Bacterium coli* colonies was not hindered by the rays, but that of tubercle bacilli was greatly retarded.

Experiments on lower animals inoculated with tubercle bacilli show that generalized infection is not prevented by exposure to the focus-tube, but the course of the disease appears to be somewhat delayed. The point has been investigated by Rieder,* Muhsam,† Lertet and Genoue,‡ and Fiorentine and Lenaschi.

That electrical currents exert a strong modifying and germicidal action upon micro-organisms is well known, and that fact may possibly constitute the fallacy of experiment which accounts for the contradictory results reported by different observers. On the whole, the balance of probability appears to be that the *x*-rays produce little positive effect upon micro-organisms, and that apparent exceptions may be due to fallacies that have not been excluded by individual experiments.

Effect of the X-Rays upon Lower Animal Life.

Dr. Kennon Dunham,‡ of Cincinnati, Ohio, has found that the *Chilomonas*, *Paramœcium aurelia* and *P. bursaria*—forms of single cell-life—were killed by exposure to the *x*-rays, and that there were no evidences of stimulation before death.

The obvious practical bearing of these researches is the indication which they afford of the possibilities of destroying epitheliomatous and sarcomatous cells. It was ascertained that the best rays for destroying both malignant cells and these lower organisms were those produced by a heavy current in a low tube with much resistance.

* *Fortschritte auf dem Gebiete der Röntgenstrahlen*, B. III., p. i., 1899, p. 36.

† *Ibid.*, B. II., 1898-1899, p. 47.

‡ *Bulletin of the Johns Hopkins Hospital*, February, 1904, p. 51.

III. MAPPING OF SKIN SURFACES.

*In the course of certain experiments with Röntgen rays the writer found that it was possible to obtain a record of the coarser fissures of the skin surface. A fairly perfect record was obtained of the skin surface, as shown in Fig. 63. The best results were secured by kneading putty into the skin, then working up the surface with glycerine, and finally gently and smoothly rubbing with subnitrate of bismuth.

As to the practical value of such a skin map there is little to be said at present. That a record can be obtained in this way of every local peculiarity seems to be undoubtedly proved by the plate; over the phalanx of the thumb a small convoluted cicatrix of the surface markings could be clearly seen in the original by means of a lens. Such a permanent record might be of value in the identification of criminals, after the fashion invented by M. Bertillon, of Paris. It seems more than likely, however, that a similar end may be obtained by simpler means. The addition of the surface markings gives a perspective effect that is wanting to the ordinary flat radiogram. The lines are evidently due to the heaping up in the furrows of a substance opaque to the rays. Under the stereoscope the radiograms of a hand prepared in this way yield a most striking effect.

The surgeon does not always find it easy to cut down upon a needle, or other small object, even when it has been precisely localized by a Röntgen-ray examination. In those parts of the body where well-marked skin furrows are found, it would be easy enough to reproduce them in the manner indicated. In that way a complete surface map, with lines of longitude and latitude, would be available as a guide to the knife of the operator.

A similar method has since been described by Laborde,† who showed radiograms by MM. Radiguet and Guichard, in which an image of the skin was obtained by coating it with substances opaque to the *x*-rays. Subnitrate of bismuth or a fine bronze powder (preferably copper-coloured), gave excellent results. The former was mixed with oil to a syrupy consistence and painted on with a somewhat hard brush. The layer of pigment applied

* From the *British Medical Journal*, March 27, 1897.

† *Bulletin de l'Académie de Méd.*, February 17, 1903, p. 208.

should be of a thickness proportional to the thickness of the part to be radiographed, and laid on evenly in successive coats so as to fill the surface furrows of the skin without leaving brush marks. Only the skin surface next the plate or screen should be painted to avoid superposition of images. The contours of the nails and underneath their free margins should be covered as well as the bony substance, and the hair may be rendered visible by using the mixture as a pomade, but somewhat more freely. Thus the relation of the skin to the bones and deeper structures could be rendered at once apparent.

B. DENTAL SURGERY

Now and then much practical help may be derived from the Röntgen rays in dental surgery. The teeth offer greater resistance than bone, and hence throw a distinct shadow when embedded in the less dense osseous substance. A good idea of the Röntgen ray photographs obtained from teeth can be gathered from the teeth shown in Fig. 157, taken from a private collection. They illustrate various pathological conditions, and may be briefly described, taken in series from above downwards, and in lines from left to right :

1. Upper molar, showing exceptional size of fangs and lateral carious cavity.

2. Upper molar, with carious cavity, nerve canals well shown.

3. Molar with carious cavity.

4. Molar with exostosis of fangs.

5. Upper central incisor : exceptional development of fang. Firmly united to its inner surface is a supernumerary tooth, faintly outlined in the radiogram.

6. Bicuspid : cavity of decay communicating with nerve canal.

7. Upper central incisor, showing sphere of erosion, which is indicated by a faint shadow at the neck of the crown. This curious pathological condition, the cause of which is not exactly known, is in its usual site partly above and partly beneath gum.

8. Upper bicuspid : eccentric distortion of fang. This shape is the result of pressure of neighbouring teeth in process of development. Absorption going on in centre of single fang is indicated by the darker area ; that is, the thin plate of tooth substance has offered little resistance to the rays.

9. Upper central incisor : half the fang absorbed ; small carious cavity. This tooth is extremely opaque, shown by its relative white look and absence of dental canal tracing, a condition probably due to its necrosis.

10. Lower molar, with large amalgam stopping reaching nearly to apex of fang; that is to say, the filling is nearly all beneath the level of the gum. The metal shown by dense white patch. Compare this absolute density to the Röntgen rays with that of the preceding tooth.

11. Permanent upper molar: fangs absorbed by pressure of wisdom tooth, which was impacted between them.

12. Wisdom tooth: fangs sharply hooked.

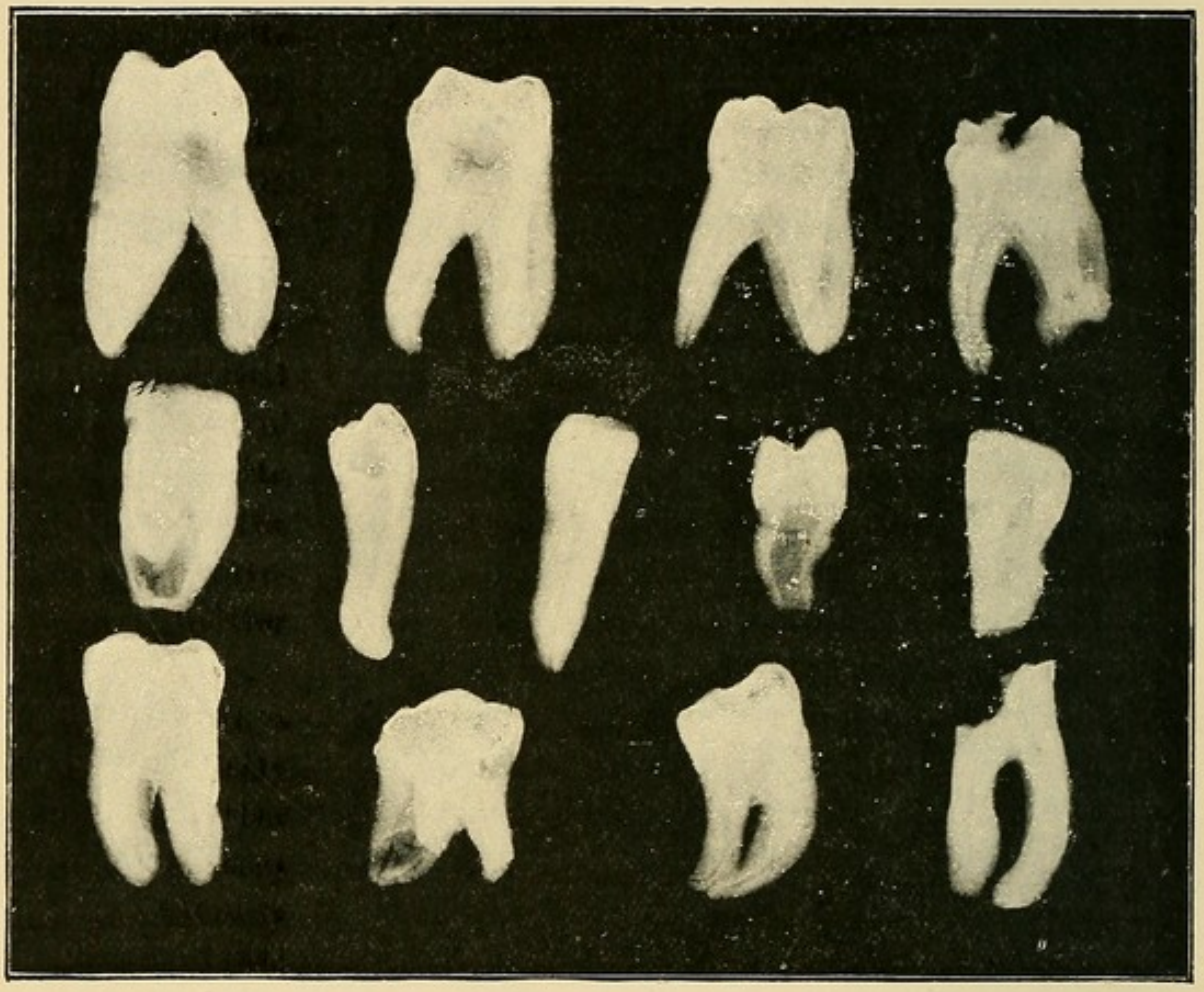


FIG. 157.—SKIAGRAM OF TEETH, SHOWING VARIOUS PATHOLOGICAL CONDITIONS.

13. Lower molar, showing convergent fangs and carious crown, rendering extraction difficult.

Mr. Frank Harrison published some of the earlier radiograms of teeth *in situ*. In the *Journal of the British Dental Association* for September, 1896, he has an excellent photograph of a portion of the lower maxilla of a girl of seven. The milk-teeth with their pulp-cavities and fangs are clearly visible, while below the roots of the first and second temporary molars are the permanent first

and second bicuspids, enclosed in their respective bony crypts. The internal dental structures of the lower jaw were displayed wellnigh as distinctly as would have been done in a dissected specimen.

Mr. Harrison observes: 'The *x*-rays promise to be of great use in dentistry, and will enable the dentist to observe in living tissues what was possible only a short time ago in the dead subject. The genesis of the teeth, the construction of artificial crowns, the anomalies of roots, the difficult eruption of teeth, and many other conditions of organs which are enveloped in tissue opaque under ordinary conditions, become visible by the illuminations of the *x*-rays.'

Dr. Kolle of New York has invented an ingenious little instrument for examining the teeth and alveoli, the dentiaskiascope, by which the operator is enabled to inspect teeth and their roots, one by one, with ease and comfort both to himself and to his patient.* It consists of a small fluorescent screen within an aluminium case, so placed that the screen-image is reflected upon a mirror, which the operator views through a tube. For taking photographs the screen is replaced by a protected sensitive film.

A number of interesting cases have been published from various parts of the world. Thus, Professor Amoedo† figured a lower jaw in which a wisdom tooth was planted at right angles to its proper axis, with the fangs buried in the ascending ramus. In the same journal M. Saussine‡ described a rare case in which an upper lateral incisor in a child of twelve lay horizontally in the bone with the fang pointing backwards. By an *x*-ray examination it was ascertained that the fang reached within 2 millimetres of the floor of the nasal fossa, and the appropriate treatment was indicated.

In one important particular the rays have proved of great service to the dental surgeon, namely, in the deformities of the jaws due to or connected with non-erupted teeth. In such cases he can ascertain with exactitude the position, shape, and size of the teeth within the bone. From the information thus gained he is able both to plan and to perform his surgical operations with exactitude, whereas under previous methods the most skilful man had to act upon probabilities. Lastly, in several pathological conditions the method will be now and then invaluable, as in the tooth-bearing

* 'The *X*-rays,' by F. S. Kolle, M.D. New York, 1897.

† *Les Rayons X*, 2 Avril, 1898.

‡ *Ibid.*, 5 Mars, 1898.

cavity in the substance of the jaw, known as the 'dentigerous cyst,' and in abscess or bony tumour of the antrum.

Mr. S. Mitchell* has found the rays useful in locating trouble at the roots of the teeth, and also for the relief of pain in an alveolar abscess.

Dr. W. H. C. Logan,† of Chicago, has found that the *x*-rays have given relief to the dull, gnawing pain of pyorrhœa alveolaris, and that the deep red, inflammatory tissue overlying the affected teeth became changed to a grayish-pink. In many cases the teeth also became firmer, and hot and cold fluids ceased to cause pain. A medium tube was employed at a distance of about 10 inches, the lips and cheeks being reflected outwards and suitably protected.

The method to be pursued in securing an *x*-ray photograph of the teeth in the living subject has been already described in Part I. The screen is here of little use.

* *Dental Record*, May, 1903, p. 214.

† *British Journal of Dental Science*, June 15, 1903, p. 546.

C. NASAL AND THROAT SURGERY

THERE are several ways in which the specialist in nose and throat diseases may gain useful information from the rays. Foreign bodies may be detected in both sets of cases. In the nasal cavity exostoses and abscesses of the antrum may be demonstrated either by a photograph or according to the method introduced by Dr. J. Macintyre, much on the lines of Kolle's 'dentiaskiascope.'

In describing this method of examining the hard and the soft tissues about the bones of the face, and those of the neck and larynx, Macintyre writes: 'The fluorescent screen is placed inside the mouth, and the lamp outside. Small discs of glass are coated with the salt and covered with aluminium, or, again, tongue-depressors, consisting of flat strips of glass covered and coated in the same way, may be employed. By placing the tube outside I am able to get an image of the septum and other parts of the cavity of the nose on the fluorescent screen in the mouth. In the same way the roots of the teeth may be seen. If the surgeon desire to examine the parts below or above the jaws he simply puts the Crookes tube below or above, and passes the rays through the tissues. If he desire to examine the tissues externally—that is to say, to pass the rays through the neck—he places a small fluorescent screen on one side and removes the Crookes tube to a suitable distance. By this means I have been able to demonstrate the presence of foreign bodies, and need hardly add that they are more easily photographed.'*

Monnier † was able to discover by means of the Röntgen rays the cause of a chronic nasal suppuration, accompanied by epiphora on the same side. The trouble was due to a lachrymal sound that had

* *Glasgow Hospital Reports*, 1898, p. 306.

† *Archiv. Internat. de Laryngologie*, No. 3, 1898.

been broken off, and remained in the lower part of the nasal duct for no less a period than forty-two years. Partial occlusion of the trachea from the pressure of an enlarged thyroid gland has been reported, also cancer of the œsophagus.

The rays have not hitherto achieved much in the ear, but it is likely that abscesses in the mastoid region could be detected. At the Röntgen inaugural meeting in November, 1897, Mr. Griffith Wilkin showed some good ray photographs of detached temporal bones. The present writer has obtained excellent figures of the semicircular canals in infants. The presence of intercranial abscess in that region may sometimes be ascertained and its exact whereabouts localized for surgical purposes.

Examination of Antrum.

Examination of Frontal Sinus.—The diagnosis of polypus, empyema, and other morbid conditions of the frontal sinuses is often an extremely difficult matter. The sinuses may be ill-developed or absent, and when present it may be impossible to say whether or not a probe has entered the cavity. By means of the radiographic screen and photograph, however, these difficulties may be overcome in the majority of instances. Scheis* has shown that the exact relation of sound to sinus may be ascertained by means of the screen. Speiss† has also written upon the subject. As a rule the sensitive plate is placed on the temple, and the photograph taken from side to side, but occasionally a record may be required in the long axis of the head, with the plate on the forehead.

* *Fortschritte a. d. Geb. d. Röntgenstrahlen*, Band 1, 1897-1898.

† *Ibid.*

D. MEDICINE

IV. REGIONAL

(*a*) Thorax and Abdomen.

It is still true that the most striking practical applications of the rays have been made in surgery, but at the same time have a firm footing in clinical medicine. In the thorax a great deal has been achieved by demonstrating changes in outline of the heart and aorta, as well as in the substance of the lungs, mediastina, and pleura. As to the abdomen proper, results have so far not been very brilliant—at any rate, in the adult. It may be confidently hoped, however, that we shall one day be able to explore all internal regions with fair accuracy.

Good results as to internal organs can be obtained in the case both of small lower animals and of children. In the illustration of the half-grown cat (Fig. 158), the windpipe and its divisions into bronchi bifurcating in the substance of the lung are well and clearly shown. The heart is outlined in front of the chest, and the bones of the sternum are visible through the less opaque cardiac substance. The delicate shoulder-blade is well recorded, and the lower margin of the thoracic cavity sharply defined by the edge of the midriff. In the head, the fangs of some of the teeth can be seen in their bony sockets, especially in the molars of the lower jaw. The cartilages of the nose and the ears are faintly shadowed, and various muscular and tendinous structures can be made out in the neck.

The abdomen of this cat was by no means so clearly mapped out by the rays, but, nevertheless, contained several valuable indications. The main mass of the liver, for instance, was sharply outlined in its upper, but diffuse in its lower margin, while a light space beneath it corresponded with the stomach. The broad light band that curved from the centre of the diaphragm to the

lower part of the lumbar spine appeared to represent large intestine. Other convolutions of intestine were clearly shown, especially in the case of a coil of gut that had an extremely light record near the

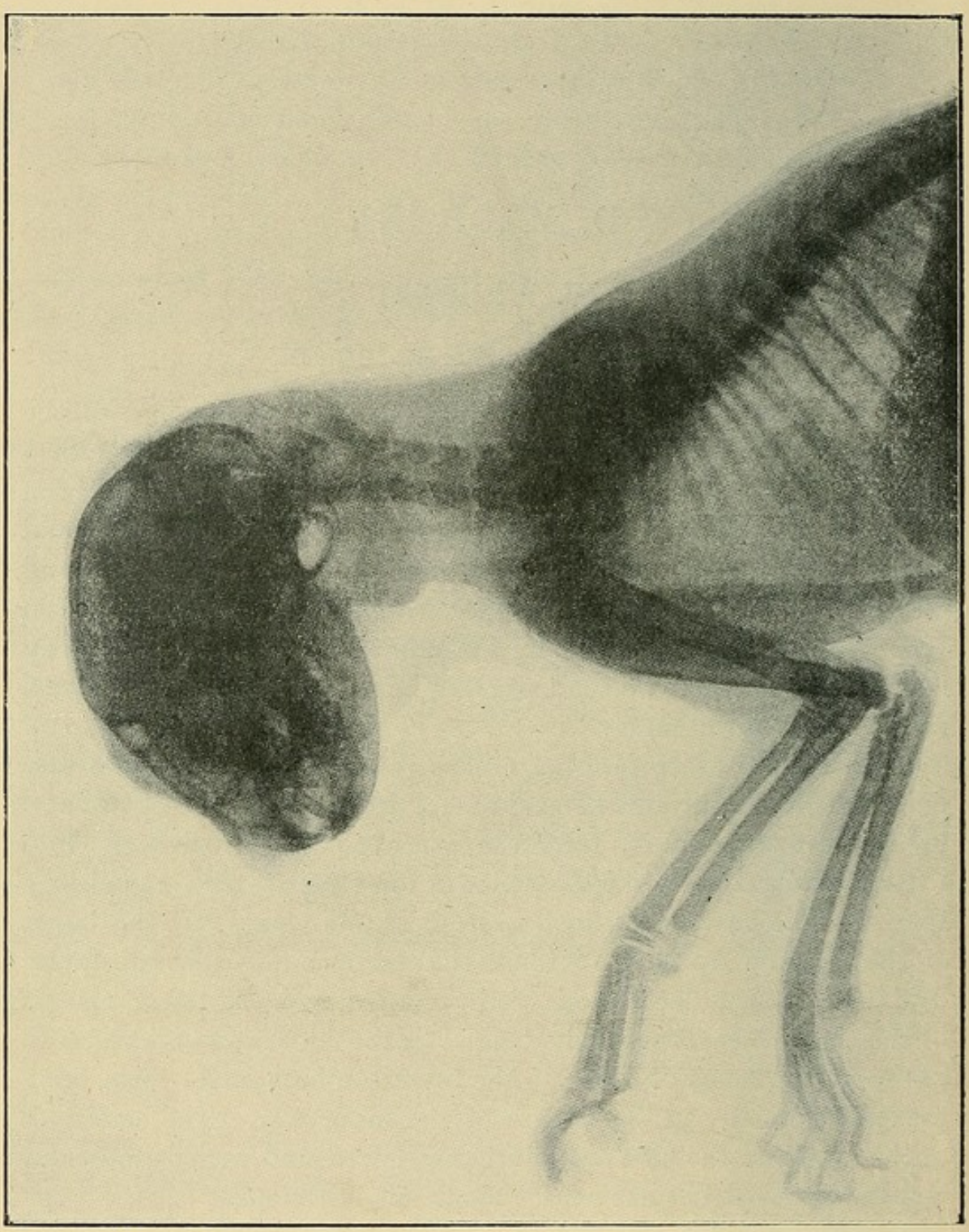


FIG. 158.—HALF-GROWN CAT, SHOWING BRONCHI, LIVER, HEART, ETC.
Reduced one-half. By Mr. Cox, Parkstone.

pelvis. This knuckle of intestine had, most likely, been full of gas, and had lain close to the surface of the sensitive plate during exposure.

The tendons, passing from the leg to the os calcis behind, and to the instep in front, were plainly pictured in the original print.

This photograph has been dwelt upon at some length because it gives a good idèa of what may be readily attained. It was taken with a coil giving a spark of over 1 foot in length. Its clearness of definition was largely owing to the fact that the animal was dead, so that there was no blurring of the shadows by the respiratory or other movements. There seems little doubt that what is possible with lower animals will one day be attainable in the case of living adult human beings, so that all deep-seated organs will be brought within the reach of this method of exact investigation. In other words, the Röntgen rays will some day render to medicine services not less conspicuous than those already conferred upon surgery.

Thorax.

Dr. Campbell Thomson,* Medical Registrar of the Middlesex Hospital, some time ago observed that the fluorescent screen is quicker and better for clinical purposes. By that means it is possible to clear up many difficulties, such as exist in aneurism both of the heart and of the first part of the aorta. He has given several valuable practical hints upon chest radiography. To get a fixed location-point, he suggests a metallic button placed over the nipple, to which it may be secured by a piece of sticking-plaster. In order to secure a record of what is seen in the fluoroscope, he fastens to the back of the fluorescent screen a sheet of white paper, through which the rays would of course pass. He then slides a flat metallic pen or pencil between the chest and the paper, and on the latter he traces the outline as projected in the fluoroscope. It need hardly be added that to carry out this manœuvre the observer would have to continue looking at the screen, so as to ascertain and control the movements of the opaque pen or pencil.

The shadow of the heart is lighter at the pulsating margin. Between it and the liver, upon taking a deep breath, a light interval appears. From the front of the chest the whole of the cardiac outline can be seen, but much less from the back, as the view is obstructed by the spine. From the back a definite shadow with well-marked external border can be seen on the left, and a smaller and less intense shadow, corresponding to the right auricle, on the

* *Lancet*, October 10, 1896.

right of the spine. The valves of a heart removed from the body and emptied of blood can usually be well seen. Sometimes the valves, particularly of the right side, are visible *in situ* in the living subject.

With the fluoroscope on the front of the chest, the position and outline of the heart is materially altered by deep inspiration. The normal state of affairs has been well described by Dr. F. H. Williams:* 'In health the diaphragm lines move as follows: Quiet breathing, ½ inch; full inspiration, 2½ to 3 inches, a little more on the right than the left side. In health the outlines seen on the left of the sternum are as follows: A part of the aorta in some patients may be observed in the first intercostal space; in the second intercostal space a portion of the pulmonary artery; the left border of the ventricle is chiefly seen in full inspiration when the apex and a portion of the lower border are also visible; the maximum pulsation is at the point corresponding to the cavity of the ventricle, about where its outline crosses the fourth rib; during full inspiration the heart moves downwards towards the sternum. To the right of the sternum the outline of the large vessels is seen, and, less distinctly, the right auricle between the second and fourth ribs.'

The excursion of the diaphragm often affords most valuable evidence. It varies with the individual, so that no absolute standard can be given. In quiet respiration the average normal excursion, as seen by the fluoroscope, may be taken as 1·7 c.m. on the right side, and rather less—1·5 c.m.—on the left. In forced inspiration and expiration, however, the greater excursion is on the left side, being 7·1 c.m., against 6·8 c.m. on the right.

From the front, then, the heart-shadow fuses on the left with that of the sternum, beyond which the right auricle projects from the third to the fifth ribs; on the right the auricular and ventricular line runs with a bold indented curve from the second to the sixth ribs. This latter line is raised and pushed upwards and outwards by the rising of the diaphragm in expiration. On the other hand, it is elongated and carried downwards and inwards towards the sternum in forced expiration, when a light, fine falciform line or a broader band defines the apex and more or less of its lower border.

* See Paper at Montreal Meeting, British Medical Association, by F. H. Williams, M.D., Boston, U.S.A.; *British Medical Journal*, April 16, 1898, p. 1006.

Ordinarily the lower portion of the heart-shadow merges into that of the liver.

If a photograph be taken of the whole heart, it is best taken with the sternum next the tube.

It should be borne in mind that fluoroscopy is an art that requires patient study. The education of the eye to recognise objects of varying opacity on the screen can be acquired simply and solely as a matter of practice. A similar observation is to a less extent true of the reading of ray photographs. Nor is it less obvious that the physician who wishes to avail himself of this branch of diagnosis must make himself familiar with the screen appearances of the heart and great vessels, and their relation to the chest-walls and midriff, as above described. He must also learn to appreciate the variations of shadow produced by shifting the focus-tube or the patient.

In examining the thorax, the shape and mobility of the ribs should be noted. The ribs are often malformed, in some cases probably from rickety bones and prolonged cough in childhood. A marked change in collapsed conditions of lung is the so-called 'roof-tile' or 'waterfall' arrangement, when the ribs drop down to much less than their usual angle with the spine, while the intercostal spaces are narrowed. In some deformities of the spinal column, the roof-tile angle may often be seen in an exaggerated form on one side of the body, while the other shows an upward compensatory tilt and widening of the intercostal spaces. The lessened angles of the ribs mean a greater amount of diaphragmatic breathing. Where the ribs are 'roof-tile' and fixed, respiration must necessarily be carried on almost, if not wholly, by the diaphragm.

The angle of the clavicles is also significant.

The author may claim to have been the first to show that a radiogram can be taken from the front of the chest. The photograph was taken from a stout man in 1898. It showed aortic aneurism and a mottled emphysematous and probably bronchiectatic lung. It was exhibited at the Edinburgh meeting of the British Medical Association in 1890, and later at the Röntgen Society.

(*b*) Heart and Great Vessels: Aneurisms, Enlargements of Heart, and so on.

The fact that the lungs are full of air and easily permeable to the rays makes it possible to get a good outline of the human heart. As the result of a number of experiments on the dead body, Pöch

demonstrated to the Vienna Gesellschaft in January, 1897, that it was possible in the empty heart to make out the valves and

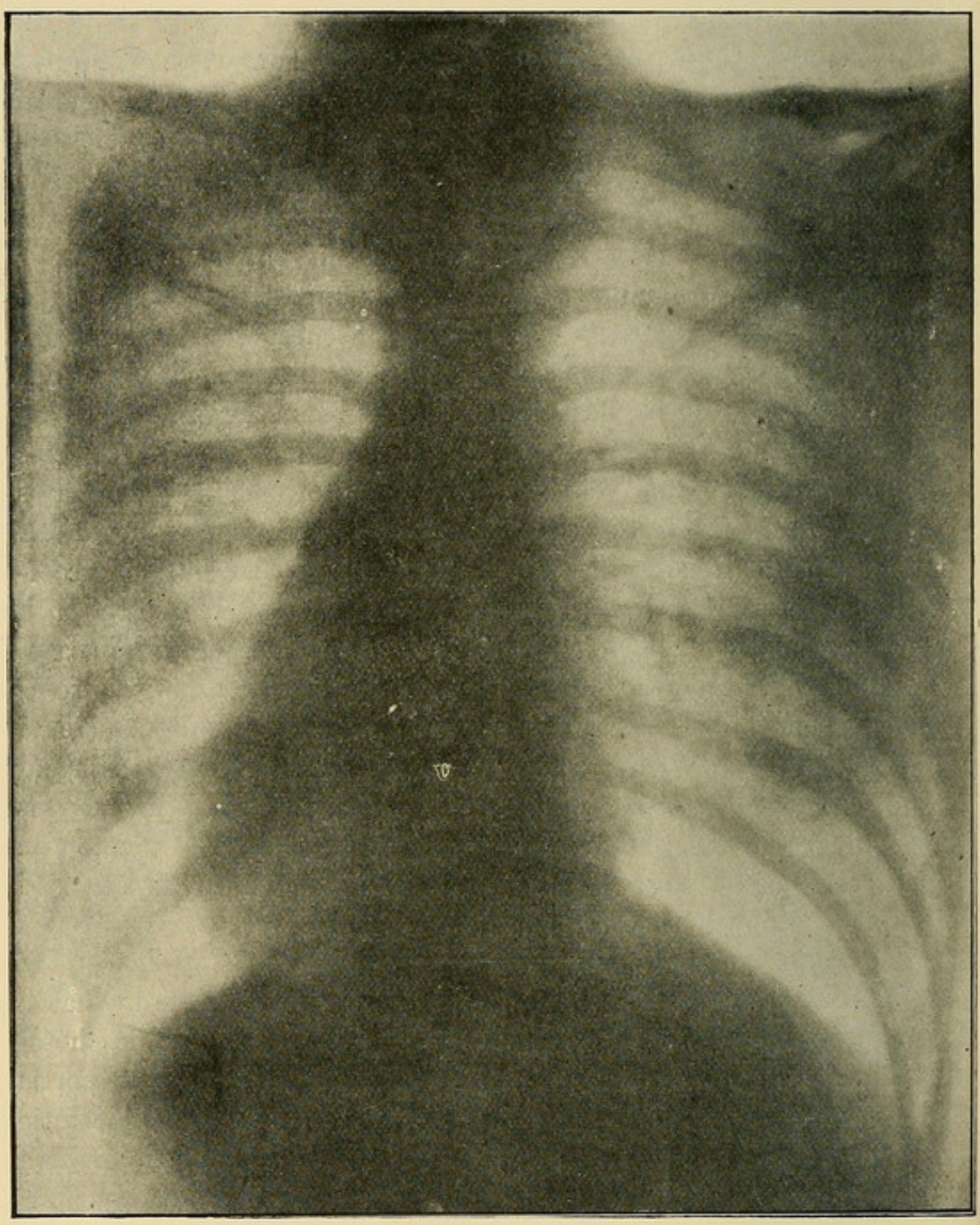


FIG. 159.—NORMAL THORAX (Short exposure).
Mr. E. W. H. Shenton.

trabeculæ as clear spaces against a darker cardiac background. When the heart cavity contained water or blood, no such differentiation could be made.

This relative opacity of blood is an important quality so far as concerns the Röntgen diagnosis of alterations in the form of the heart and bloodvessels. The reason why a bloodvessel should resist a long exposure is obscure. We know that after prolonged exposure both biliary and uric acid calculi will cease to cast any shadow, while a rib nearly ceases to do so, and a phosphatic shadow becomes much lighter (Dr. Swain's experiment, p. 174). Mr. C. W. Mansell-Moullin mentioned to the writer a case in which the abdomen was exposed for two hours. The bones left no record, but the abdominal aorta threw a strong shadow.

Clearly the widespread movements of respiration affect more or less the whole contents of thorax and abdomen, while the heart and great vessels, normal and abnormal, are in a state of intermittent motion. Instantaneous photography, were it possible, would enable one to ascertain the exact position of any movable internal part at any fractional time within its periodical range of movement. Thus some forms of rapidly expansile aneurisms are recognisable on the screen, whereas they cannot be photographed.

So far as concerns the respiratory movements of the chest and abdominal walls, satisfactory results may be now and then obtained by causing the patient to fix the part to be photographed by leaning it against a chair or other firm object, upon which the plate is placed. Thus in taking gall-stones or a tumour in front of the kidney, the patient stands upright and leans against a projecting angle of wall; in examining an asthmatic lung, the patient sits astride a high-backed chair, against which one side of the thorax is pressed.

Dr. Disan* has introduced an ingenious method of recognising alterations in the cardiac outline. First of all he marked on the chest what should be the normal shape of the heart, and mapped out the area thus obtained with a copper wire, which he fastened to the chest with ordinary plaster. He then examined with the fluoroscope in the following way:

'At first the greatest strength of current obtainable from the apparatus is turned on. The observer then looks through the fluoroscope, and gets the chief landmarks of the chest—such as the scapula, ribs, spine, and convexity of liver—the wire being at the same time in view. The current is then reduced until the heart becomes visible. The fluoroscope is applied to a spot marked at the

* *Dominion Medical Monthly*, February, 1897.

left of the spine corresponding to the fourth intercostal space in front of the chest.'

In a case, under Dr. Coupland, of doubtful deep aneurism of the chest, the diagnosis was cleared up by the fluoroscope. From the front, slight hypertrophy was noted, and just above the junction of the left cardiac border with the sternum a faint indefinite shadow. From the back, a well-defined shadow was seen on both sides of the spinal column, at about the level of the fourth dorsal vertebra. On the right border this outline was convex and pulsating; the intensity of the shadow on that side was almost the same as that of the heart, while on the left it was lighter and less definite. The evidence thus obtained converted a doubtful into a certain diagnosis.

Excluding fluid, the pulsating margin of a non-cardiac shadow in the thorax points to aneurism. The observer, however, should remember that bulgings are not uncommonly found in the aorta, and that the heart movements may be communicated to tumours or enlarged glands.

Aneurisms may at times be detected by the rays in the thorax when their presence cannot be demonstrated by percussion and auscultation. Several cases of unsuspected thoracic aneurism revealed by the screen have come under the observation of the present writer. In one instance he took a Röntgen photograph of the chest of an elderly asthmatic of heavy build. A good-sized aneurism was seen in the left upper thorax, where, owing to the large and emphysematous lungs, it could not be diagnosed by ordinary physical signs. Indeed, an experienced physician subsequently denied in court that an aneurism existed.

A dilated aorta can be seen from the back on the left side of the vertebral column. Bouchard says that when aortic insufficiency is present, pulsating aortic shadows are visible on both sides of the spine—that is, in the ascending and descending portions of the aorta.

In discussing the diagnosis of aneurism by the Röntgen rays, Dr. Hugh Walsham* dwells on the value of the lateral oblique method introduced by M. Mignon of Nice. As all practical workers know, nothing definite is shown by a strictly lateral examination of the chest. By a three-quarter view, however, much may be learned as to the condition of the mediastina. On the screen may be seen in this way a triangular clear zone, which M. Mignon calls the

* *Edinburgh Medical Journal*, April, 1901.

retrocardiac triangle, bounded below by the convex shadow of the diaphragm, in front by that of the heart, and behind by that of the vertebral column. The last-mentioned or posterior boundary includes the shadows of aorta, vena cava, and œsophagus. There is another clear triangular space seen in front of the heart shadow corresponding to the anterior mediastinum.

'Tumours originating in the anterior mediastinum,' writes Dr. Walsham, 'can occasionally be well seen in this way. Any bulging of the vertical vertebral spinal shadow would indicate an aneurism springing from the thoracic aorta, or an œsophageal tumour, the rarity of the latter, however, making an aneurism probable. The anterior triangular clear space is seen readily enough, but the shadows in the retrocardiac triangle are more difficult; but I have seen this retrocardiac triangle filled up with shadow in a case of enlarged mediastinal glands.'

The necessity for caution in interpreting Röntgen ray examinations of the chest is shown by the following case, related by Kirchgaesser:* In a woman, aged seventy-five, the fluorescent screen revealed a dark shadow with expansile pulsation just above the heart shadow. Aneurism of the aorta was diagnosed, but post-mortem it was found that the aorta was firmly adherent to the œsophagus, owing to a carcinomatous growth, which arose from the cardiac end of the stomach. There was no aneurism, and the shadow thrown on the screen was probably due to the distention of the œsophagus with fluid.

Dr. Mignon, in a paper† read at the International Congress of Electrology and Radiology at Paris, in 1900, advocated a lateral oblique method of examining the chest. By placing the screen in a postero-lateral position, he discloses what he calls the retrocardiac triangle, bounded below by the diaphragm, in front by the heart, and behind by the vertebral spine, which includes the shadows of the aorta, vena cava, and œsophagus. In aortic aneurism the anterior border of the last-mentioned shadow is not vertical. If the screen be placed antero-laterally a clear space is seen between the heart and the sternum, corresponding to the anterior mediastinum. Dr. Mignon's method appears to be valuable for the examination of the mediastina. Its results, however, are not likely to equal those obtainable by a stereoscopic examination of the same region.

* *Münch. Med. Woch.*, May 8, p. 646.

† 'Examen du Médiastin par le Radioscopie et la Radiographie,' par Dr. M. Mignon, de Nice. G. Stembell, Paris, 1900.

Hypertrophies of the heart are readily examined on the screen. In those of the left ventricle the apex elongates, and the clear space usually seen between the heart and liver on deep inspiration is either diminished or disappears altogether.

The screen phenomena of right-sided hypertrophy are thus described by Régnier: 'In hypertrophy of the right ventricle, the

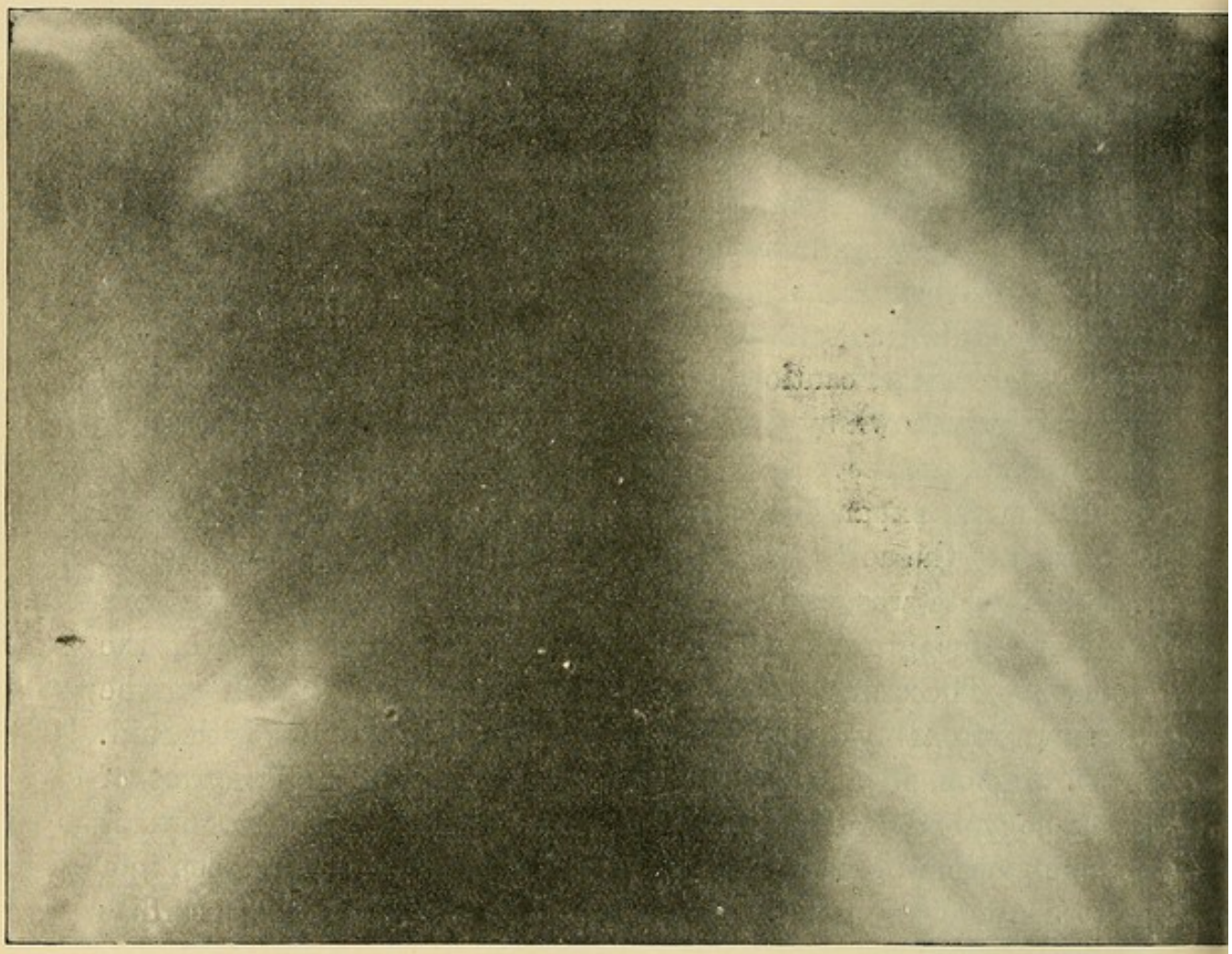


FIG. 160.—ANEURISM OF AORTA IN WHICH PHYSICAL SIGNS WERE ABSENT. (Diagnosis, aphonia from recurrent laryngeal neurosis. Large fusiform aneurism involving entire arch of aorta. J. M. Scott, M.D., *American X-ray Journal*, July, 1898.)

heart, drawn down at the base, tends towards a horizontal position. When the right ventricle undergoes excessive enlargement, there may be twisting around the longitudinal axis of the heart, and the right ventricle is pulled to the front. One recognises that fact on the screen because the shadow of the right heart becomes more distinct when the patient is examined from the back than from the front. There may also be a twisting of the heart around the vertical axis

of the body, the base being directed backwards and the apex to the front. This twisting is visible when one examines the patient from the left side: the cardiac cone is then sharply shown in its whole length. In compensatory hypertrophies of the heart from sclerosed arteries or renal disease, the auricle can be seen beating to the left of the sternum.*

Dr. Régnier mentions a case which he saw under Professor Potain. The patient suffered from acute dilatation of the heart, and the condition was registered on several Röntgen photographs, which, in spite of their want of sharpness, nevertheless enabled one to follow the gradual disappearance of the dilatation and to preserve a graphic record of the occurrence.

Transposition of the Heart.—Many instances of this congenital abnormality have been published. When the heart is pushed over to the left side by the pressure of effused fluid, it is readily seen in its new position. An excellent illustration of a right-sided cardiac displacement in pyo-pneumothorax is given on p. 337.

Dextrocardia.†—M. J. Garel‡ has a good illustration (Fig. 161), which we reproduce by courtesy of the *Medical Review*.

M. Chatur§ insists on the importance of the axis in dextrocardia. In congenital cases the vertical axis is reversed. In acquired cases the axis indicates the extent of the action, and any change in it helps the prognosis. Most of his acquired cases were tubercular.

Sinistrocardia.—M. A. Chauffard‖ has published an interesting case of a man, aged twenty-one, whose mother died of phthisis. At ten he had an attack of hæmoptysis, and on admission pain, cardiac palpitation, cough, and dyspnœa, but no bacilli were found in the sputum. The heart was displaced to the left, and the apex retracted. Radioscopically the left lung was opaque and contracted. The left diaphragm was higher, and its excursions lessened. During deep inspiration, the mediastinum was displaced to the left side. The right border of the left heart-shadow, which was parallel with the right border of the vertebral column during expiration, disappeared behind the vertebral column on deep inspiration.

Radioscopy thus showed left pulmonary sclerosis, most marked at the summit, with mediastinal adhesions; sclerotic mediastinitis,

* 'Radioscopie et Radiographie Cliniques,' Dr. Régnier. Baillière, Paris, 1898.

† *Medical Review*, 1902, p. 353.

‡ 'Bull. de Soc. des Hôp. de Lyons,' p. 85, 1902. § *Op. cit.*, 1902, p. 89.

‖ 'Bulletin de la Soc. Méd. des Hôp.,' p. 132, 1902.

with pericardial adhesions; traction of the large vessels, particularly of the pulmonary artery to the left. As a physical sign, the mediastinal displacement during inspiration is pathognomonic. It can be demonstrated by light percussion, but radioscopy is the only trustworthy test.

Sinistrocardia has rarely been met with, and dextrocardia is relatively uncommon. Their recognition is, however, of much

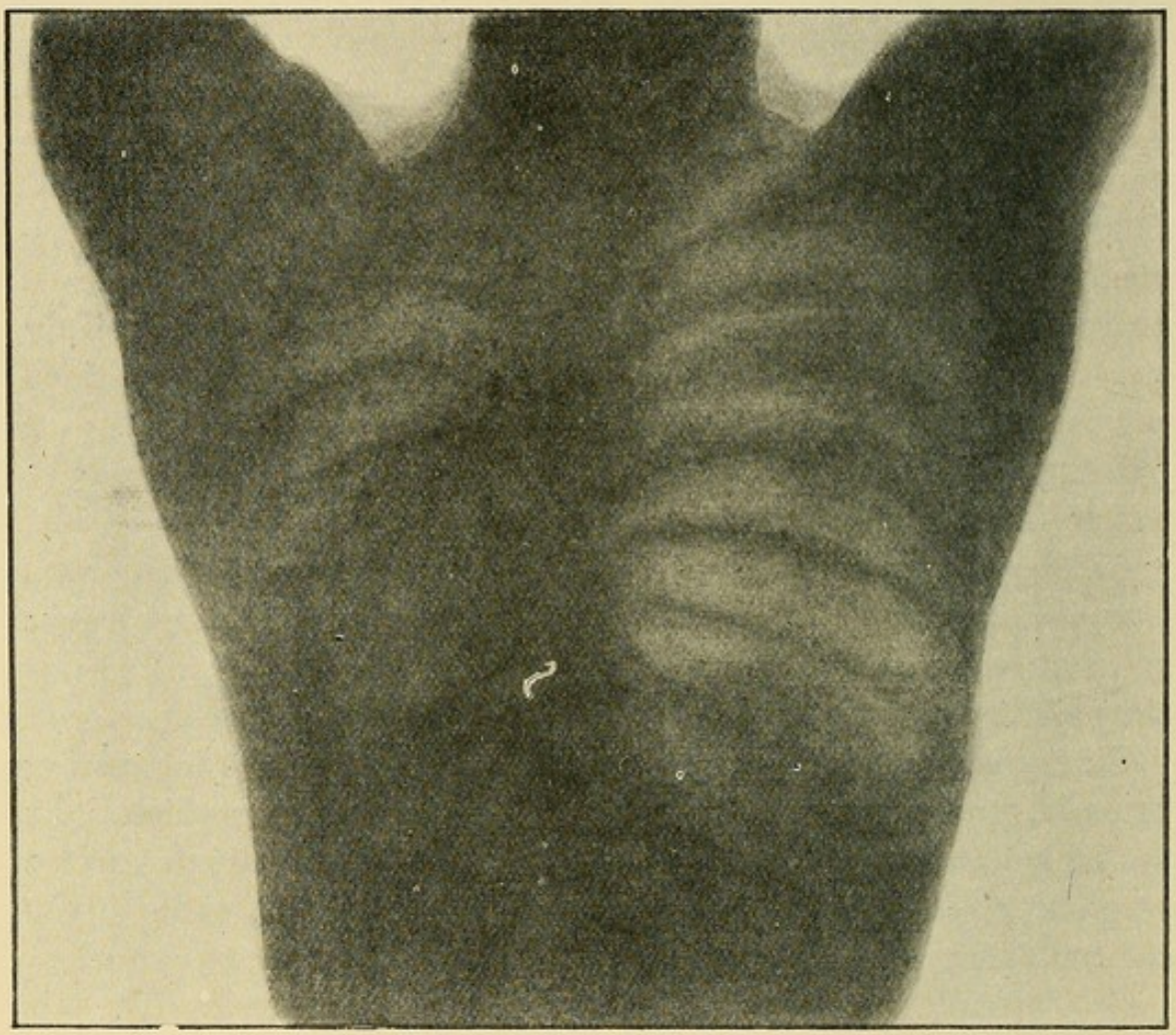


FIG. 161.—DEXTROCARDIA.
M. J. Garel.

importance with regard to prognosis, as, when once the condition is established, little compensation can be provided, and cardiac failure and arrest soon prove fatal.

By the courtesy of the *Medical Review* we are enabled to present the original outlined illustration of the heart displacement (Fig. 162).

Reported Action of X-Rays upon the Heart.—Mr. Bezley Thorne* has made an interesting observation in relation to cardiac

* *British Medical Journal*, vol. ii., p. 1238, 1896.

radiography. He noticed that the heart shrank visibly after thirty minutes' exposure to the Röntgen rays. In one case the lessening amounted to no less than 2 inches in the long axis of the viscus, and $1\frac{1}{2}$ inches in the short diameter. There may, of course, be some fallacy involved in this observation. For instance, it is known that increased exposure to the rays or an alteration of current in many cases means greater penetrability of any given substance. So that the appearance of a light zone round the heart towards the end of a

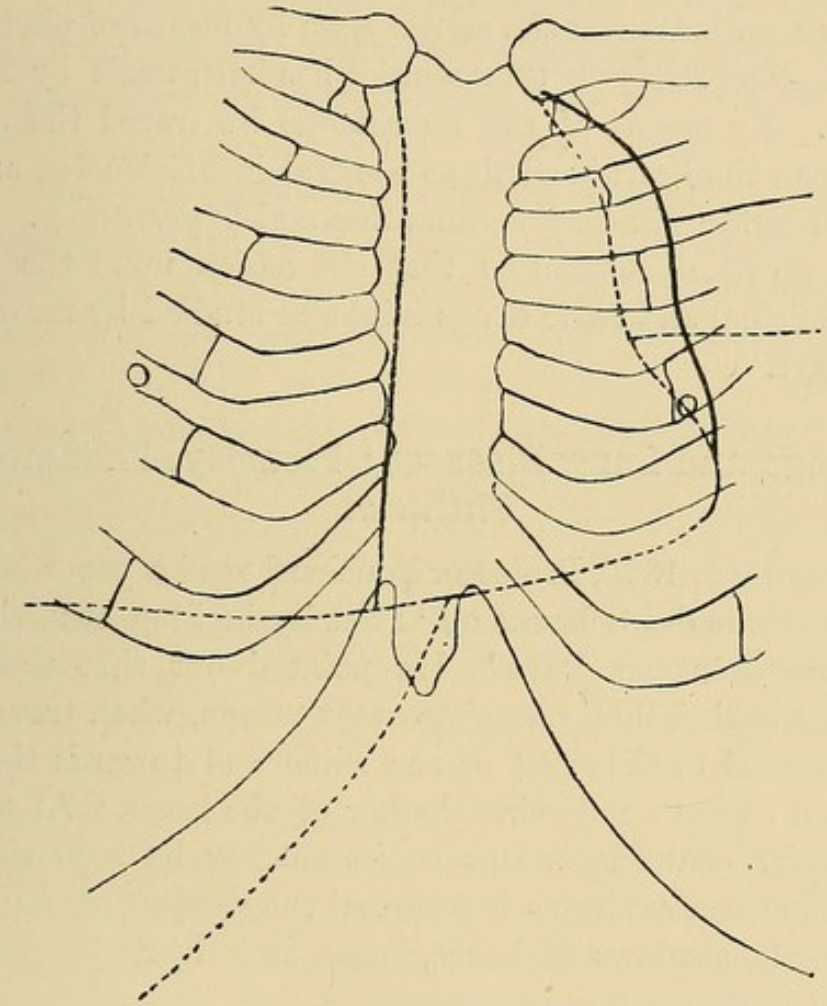


FIG. 162.—SINISTROCARDIA.
M. A. Chauffard.

long exposure might mean that so much of the muscle had become fully penetrated, or that the electrical conditions had changed. In either case the dark core would probably represent blood or dense muscular tissue, or both.

Should, however, actual contraction be proved, it points to possibilities of importance. Without venturing too far afield in abstract speculations, it seems tolerably clear that, assuming such contraction, there might be direct tonic influence on heart muscle,

while traumatic injury to deep organs from the Röntgen exposures might be connoted. In this connection it may be noted that Dr. H. Heincke found extensive pigmentation occurs in the cells of the splenic pulp of lower animals after the abdomen has been exposed to the action of *x*-rays.*

Atheroma of the Aorta.

Atheromatous patches have been demonstrated in the aorta, and are usually seen better on the screen than by means of photographs.

An interesting study in therapeutics has been made by Professor Grunmach. By means of the fluoroscope he traced the action of digitalis upon the heart in aortic and mitral insufficiencies, and other conditions resulting in cardiac dilatation and hypertrophy. He also made the practical suggestion that the action upon the heart of various medicinal and toxic drugs might be studied by means of the Röntgen rays.

(*c*) Lungs and Lung Diseases: Pleurisy, Pneumonia, Phthisis.

On December 7, 1896, Professor Bouchard read a paper before the French Académie des Sciences on 'Pleurisy in Man studied by the Help of the Röntgen Rays.' He pointed out that the thorax, viewed from behind by a phosphorescent screen, when traversed by the rays, showed to the right of the spine and towards the middle of the dorsal region a pulsating shadow of the heart. At the same time the liver could by means of its shadow be seen rising and falling in the chest cavity as it followed the respiratory movements. Apart from the shadows of bones, heart, and liver, the rest of the interior of the thorax was transparent.

In a right-sided pleurisy with effusion, Bouchard found a darker shade on the affected side of the chest as compared with that of the sound. Further, the shadow indicated the upper limit of the effusion, as proved by percussion and by other ordinary methods of physical diagnosis. The tint, moreover, grew deeper from the upper border, where the layer of effusion was thin, to the lower part, where the shadow merged into that of the liver.

In three cases he also noted to the left of the vertebral column a triangular shadow, the base of which was continuous with the heart.

* *Münch. Med. Woch.*, No. 18, May 3, 1904, p. 785.

This he explained as the mediastinum pushed sideways to the left by the effusion. In a fourth case, retraction of the affected side had drawn the mediastinum to the right.

In a further communication to the Academy (December 14), the professor remarked that, in most of the cases of pleurisy with effusion previously described, he had noted with the fluoroscope that the lighter area increased from above downwards as the effusion lessened. In one case, however, the apex of the chest retained its shadow. This fact suggested consolidation of the lung at that spot, a suspicion that was confirmed by percussion and auscultation. In other instances tubercular deposits were localized by the same method.

'In all tuberculous subjects,' writes Dr. Bouchard, 'examined by the phosphorescent screen, I have established pulmonary lesions by a shadow, the area of which corresponded with that mapped out by other methods of physical examination, and the intensity of which was in relation to the gravity of the lesion. In two instances the appearance of clear spaces pointed to cavities, a diagnosis verified by auscultation. But in a third case, where auscultation led one to suspect the existence of cavities, nothing of the kind was visible on the screen. In another patient the general symptoms pointed to early phthisis, but no tubercle bacilli were found in the sputa, and the physical signs were indecisive. The skiascope showed that the apex of one of the lungs was less permeable to the rays, and in a few days both auscultation and bacteriological examination of the sputum yielded positive results.'

Some no less important reports were published by the same observer in the succeeding issue of the *Comptes Rendus* (December 28). In one case the whole left lung was obscured. This appearance was attributed either to pleurisy with effusion, or to general tuberculosis of the left lung. On further examination it was noted that the mediastinum was not pushed to the right. By a process of exclusion, therefore, the diagnosis of tubercle of the whole left lung was arrived at. In another case, on the left of the spinal column in a little girl, was demonstrated a tumour, due to adenoma of bronchial glands. In a third patient, a dark shadow on the right side of the chest, continuous with that of the sternum, was shown to be due to a transposed heart. Owing to the heart's impulse being on the right side, the presence of aneurism had been suspected. Other conditions recognised include aneurism of the arch of the aorta,

with a clear view of its position, outline, and size; pulsation of the aorta to the right and left of the sternum; compensatory hypertrophy of the heart in arterio-sclerosis; and beating of the auricles to the right of the sternum, in dilatation due to kidney disease.

At the Medical Club in Vienna, in January, 1897, Professor Wasserman showed two cases that he had diagnosed by the Röntgen rays. The first was a case of phthisis in the right lung, where the cavernous signs could not be elicited by percussion and auscultation. Under the rays the left side of the chest appeared clear and healthy, while the right exhibited diffuse shadows representing infiltration; in one place a clear area, which to all appearance corresponded to a cavity, was brought out by the tube when applied either in front of or behind the right lung. The second case was that of an aneurism in the left mediastinum, where the fluoroscope demonstrated a dark space, the margin of which moved with a distinct impulse, and thus established the differential diagnosis between solid tumour and aneurism.

Lévy-Dorn examined with the screen the chest of a patient suffering from chronic bronchitis and asthma. He observed that the left half of the diaphragm fell rapidly at each inspiration, while it rose by slow successive stages. The right half, on the other hand, remained from the first absolutely fixed in the position of extreme inspiration, only to rise at the termination of the attack with the expectoration of viscid mucus.

Lawson and Crombie* have contributed an interesting paper on the Röntgen rays in the diagnosis of lung diseases. Among other points, they insist on the value of the lighting up of the healthy or emphysematous apex on the screen during deep inspiration, whereby an infiltration is at once excluded. The level of the apex on each side can also thus be clearly demonstrated. Where there is doubt as to whether bronchial pressure is caused by aneurism or by enlarged glands, a pulsating shadow on the screen has sometimes settled the presence of aneurism. The absence of respiratory rib movements, partial or complete, in collapsed lung and intrathoracic tumours is noted, but the physical signs are so marked that the screen evidence is of little assistance. A local restriction of the movements of the ribs, however, may be of real value in determining the presence and extent of early tuberculous disease. 'Emphysema,' they observe, 'is recognised by the abnormally light appearance of

* *Lancet*, July 25, 1903.

the lung, the widening of the intercostal spaces, the raising of the angle of the clavicles, and, if not uniform, by cardiac displacement.

Dr. Halls Dalby* has written an excellent thesis on the radiographic diagnosis of pulmonary disease. He suggests the non-commital terms 'transradiant' and 'transradiancy' to replace 'translucency' and 'transparency.' Certain faint lines or streaks often found in radiograms following the outline of the cardiac shadow he regards as due mainly to pericardium, and also to the junction of the parietal pleura, on which account he names them 'pleuro-pericardial lines.' He does not agree with Dr. Walsham that they are records of visceral pleura seen edgewise, because they appear after the lung has been stripped of that membrane. Nor does he accept the view that they are connected with bronchi or mediastinal glands, inasmuch as the former produces a light defined, and the latter a dark, irregular area. The fact that the lungs brighten on deep inspiration he attributes to the greater amount of contained air. At the same time he mentions Dr. Williams'† view that the greater transradiancy was due to the lessened amount of blood, inasmuch as he noted no such difference in comparing inflated with collapsed lungs removed from the body.

In a table Dalby records the range of mobility of the diaphragm in twenty cases of pulmonary tuberculosis. He noted diminution of excursion in the great majority on the side most affected, the general rule being that in quiet and normal breathing the excursions are equal on the two sides, but on maximum respiration they are slightly greater in extent on the right than on the left side. In two cases the movement of the diaphragm was jerky and interrupted, and in others undulatory.

Dr. Dalby makes the important statememt that almost certainly pulmonary tuberculosis, which has gone far enough to cause physical signs, is never unilateral. He mentions the case of pulmonary embolism due to mitral stenosis, which stimulates the physical signs of tuberculous apex (impaired percussion note, prolonged expiration, and dry crepitation). Screen examination would at once show in pulmonary apoplexy a shadow of medium density obscuring the whole of the upper tube of the implicated lung. He also points out that, however damaged the base of the lung may be, there is always

* *Lancet*, June 27, 1903 (Abstract).

† 'The Röntgen Rays in Medicine and Surgery,' 1902.

a clear irregular space to be seen on the outer side, formed by the inward curving shadows of lung above and diaphragm below.

A good illustration of the relative value of Röntgen methods may be gathered from the notes of the following case reported by Dr. Dalby :

Case 8. — The patient was a woman aged thirty-three years, who had complained of cough during the previous seven months with profuse expectoration. She had slight hæmoptysis on the day when she came to hospital. Her appetite was fair, and there were no night sweats or wasting. A physical examination of the chest showed anteriorly dulness and bronchial breathing in the right joint below the clavicle as far as the third rib. A radioscopic examination with the tube anteriorly showed on the right side a shadow as far as the fifth rib, and on the left side a shadow as far as the third rib. With the tube posteriorly it showed a shadow at each apex as far as the clavicles and the first rib. The diaphragmatic movement was with quiet respiration ½ inch on both sides while with maximum respiration it was 2⅛ inches on the right side and 2½ inches on the left side. In this case, although physical signs pointed only to unilateral involvement, yet on screen examination both sides were seen to be in 'shadow.'

Tubercle of the lungs may sometimes be found by the Röntgen rays in an early stage, when it could not be detected by ordinary means. The importance of such early diagnosis in these days of improved treatment of pulmonary phthisis can hardly be over-estimated. Another fact is that the rays not infrequently show the disease to be more extensive than had been mapped out by physical examination. When Koch's tuberculin treatment for consumption was on its trial, the writer recalls a case in which tubercle was diagnosed in the right apex, but careful and repeated examination revealed none in the left lung. The injection of the drug was followed rapidly by the appearance of a dull area at the left apex. Had the focus-tube been available in that instance, there can be little doubt that the early invasion of the left lung could have been equally well demonstrated. An *x*-ray photograph of the lungs, then, may afford valuable confirmatory evidence when combined with the injection of tuberculin for diagnostic purposes.

In one case the author was enabled to obtain a record of individual grey miliary tubercles in the lungs of an infant that died from acute tuberculosis. The original radiogram was shown at the Portsmouth meeting of the British Medical Association. Unfortunately most of the sharp detail of the original is lost in the reproduction shown here by the courtesy of the *Hospital* (see Fig. 163).

One of the most constant and significant signs is the limited excursion of the diaphragm. Tubercular shadows, if the disease be

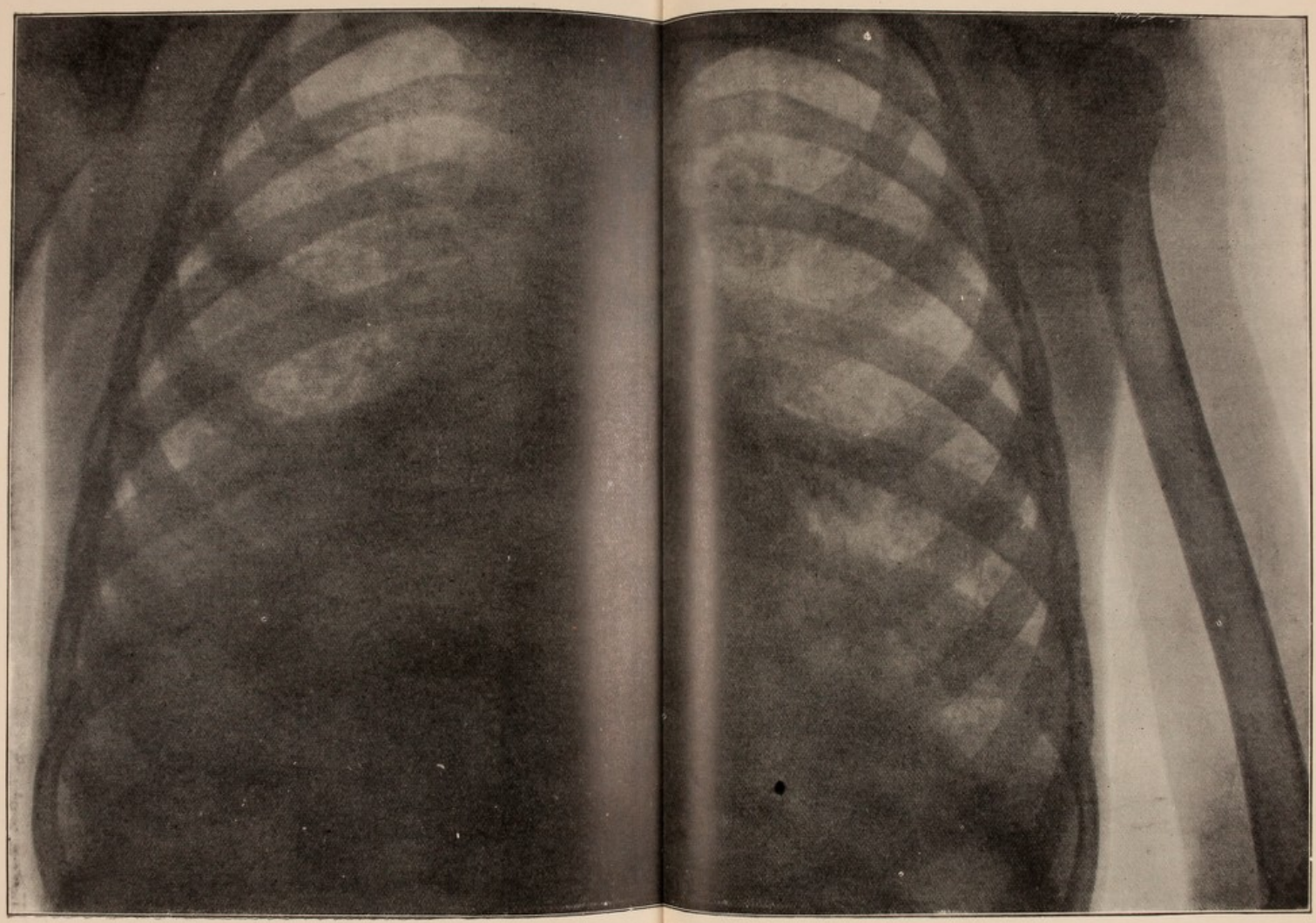


Fig. 163.—Thorax showing Scattered Miliary Tubercles.
(Reproduced by permission of the *Hospital*.)

[*To face p.* 334.

diffuse, may be hazy and faint. Where there is consolidation, however, the shadows are more or less patchy, and darker than the ribs. In pleurisy the shadow is dark but uniform. The heart, it should be borne in mind, may be drawn towards the affected side by the contraction of the lung and its lessened expansion.

The localization of diseased areas in the lung is now brought within the reach of the surgeon, who has hitherto been hampered in his attempts at lung surgery by the often misleading nature of physical signs. Supposing a shadow to be fairly defined, its exact position could of course be ascertained by the ordinary methods of stereoscopy and localization. The altered density of tissue may show in various degrees from a slight haziness to a dark shadow; when extremely dark it may be due to pleuritic thickening and adhesions. In tuberculous cases the collar-bone is often partly, or even at times altogether, obscured. A cavity, when empty, shows as a clear space, but when full of pus or other fluid as a dark spot. Pulmonary echinococcus has been noted.

An important case has been reported by Messieurs Varcot and Chicotot* of a child, nine and a half years of age, in whom the rays revealed a central pneumonia, not ascertainable by the ordinary methods of percussion and auscultation.

The progress of the disease in the lungs can be accurately noted, and it is possible in the majority of cases to say with confidence whether the tubercular area has increased or decreased in size. A valuable graphic record of events can be preserved in the shape of a series of Röntgen photographs, or, failing that, of charts mapping out the results of periodical screen examinations.

The causes of dyspnœa may sometimes be revealed by the rays when not ascertainable by other methods.

The various stages of pneumonia can be seen by the rays—consolidation, collapse, pleuritic effusion, displacement of heart, impaired respiratory descent of diaphragm. The gradual clearing up of the diseased process can also be followed.

Cirrhosis of the Right Lung with Displacement of Heart.—An interesting case of this condition has been published by Dr. Henry Waldo,† of Bristol. The patient was a boy of ten, with good family history. The heart's apex was found beating outside the right nipple; the whole right lung yielded an impaired percussion

* *La Radiographie*, Avril, 1899.

† *British Medical Journal*, December 17, 1898.

note; and repeated examinations of the sputa failed to reveal tubercle bacilli. The Röntgen photograph showed great density of the affected lung, and absence of heart in left thorax. The case appeared to be one of diffuse interstitial pneumonia, affecting the whole lung, unconnected with tubercle, and by its contraction leading to an extreme displacement of the heart.

Impairment of respiratory movement is an important negative sign. It is shown on the screen by the lessened movement of the diaphragm, both in ordinary and in forced respiration. According to Williams,* the lessened descent of diaphragm in some cases precedes the increased density of the lungs, and is therefore to be reckoned among the earliest signs of pulmonary disease. In pneumonia, the return of normal rise and fall of the diaphragm is a more delicate test than the opacity of the lung. In emphysema the the diaphragm descends lower towards the abdomen than in health, and does not rise to so high a point as it should, while the lung area is brighter than normal. In pneumothorax the diaphragm is very low down on the affected side, and motionless, except at its median end, where it sometimes moves with the sound side. The diaphragm may also be restricted in its range by pleuritic adhesions.

The diaphragm may also be pushed up, and restricted in movement by various abdominal conditions, as dropsy or enlarged liver.

Pneumothorax.

A good *x*-ray illustration of pneumothorax has been published by Mr. Ernest Martin, M.B.,† of the City of London Hospital for Diseases of the Chest, by whose courtesy the block is here reproduced. The patient was a man, aged twenty-two, suffering from tuberculosis. Mr. Martin says: 'In a case such as the above there is, of course, no difficulty in making a diagnosis of the condition present, and the chief interest of the skiagram, apart from what may be learned from it by the practical *x*-ray worker, lies in the clear demonstration of the position of the displaced viscera in a case where the lung is not firmly bound by adhesions, and when there is a positive pressure within the pleural cavity. The flattening and downward displacement of the diaphragm could hardly be made out by the physical signs; the position taken up by the lung, and the

* *British Medical Journal*, April 16, 1898.

† *Lancet*, September 28, 1901.

complete displacement of the heart from the left side of the chest, are all clearly shown in the diaphragm. Another point well brought out is the broadening of the intercostal spaces on the side of the pneumothorax. In addition, the skiagram shows the shadows thrown by the caseous tubercles, the portion of the lung immediately above the right arch of the diaphragm being the only clear piece of lung shown.

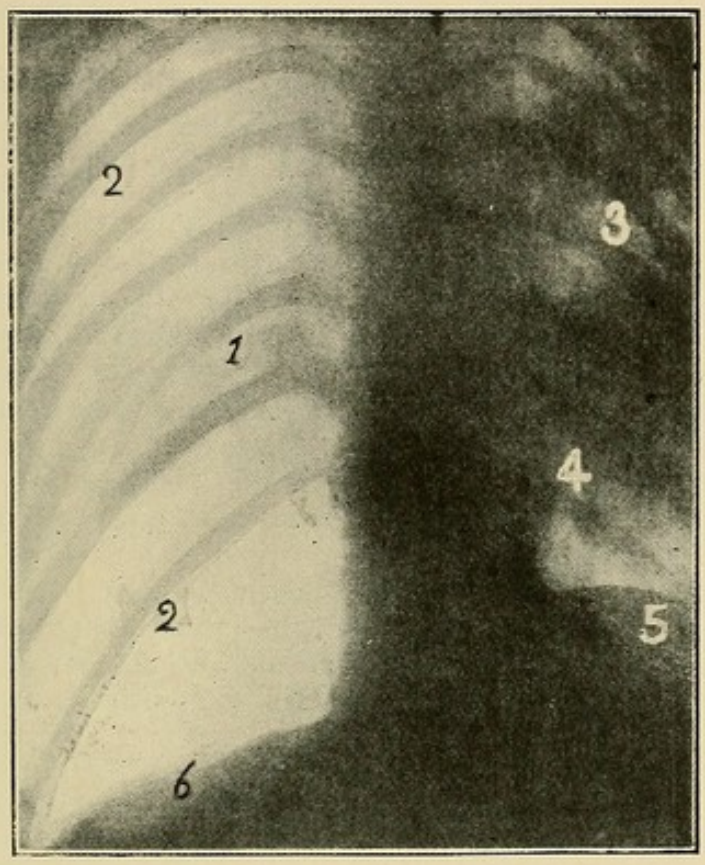


FIG. 164.—PNEUMOTHORAX.

1. Collapsed left lung. 2. Air in pleural cavity. 3. Tuberculous lung. 4. Right margin of heart. 5. Right dome of diaphragm, normal. 6. Depressed dome of diaphragm. (*Lancet.*)

A most interesting case* was shown at the Vienna Medical Club, April 20, 1898, by Dr. R. Kienbock. The patient, aged twenty-four, came from the clinic of Professor Schroetter, and had suffered for five months from pyopneumothorax. The published details are so instructive that they may be reproduced at some length, especially as, thanks to Dr. Kienbock's courtesy, the description is accompanied by the orginal illustration :

* *Medical Press and Circular*, October 26, 1898.

'Examination of the patient by the screen, the patient being in the erect posture, gave the following results: Corresponding to the right lung there is a long, rather light zone, the upper part of which is darker. The left half of the thorax presents altogether different appearances. The upper third is fairly light, the middle very light, while the lowest part is very dark. The upper limit of this dark field behind corresponds to a horizontal line situated two fingers' breadth above the level of the angle of the scapula. The contrast between the transparency of the middle area and the opacity of the inferior area is very marked; but even in the latter one can make out the form of the ribs, which appear as still darker lines. The dark shadow merges below into a lighter shadow of the abdomen without any distinct line of demarcation. The shadows thrown by the sternum, the great vessels, and the vertebral column are not broader than normal. The shadow of the heart is displaced far to the right, and it can be discerned extending some distance down into the dark zone.

'It is easy to detect various movements in the image. On the right side the shadow of the liver descends several centimetres with each inspiration, while on the left the level of the dark zone ascends during inspiration for three-quarters of the width of the intercostal space. The ribs are raised with inspiration on both sides. The shadow of the enlarged heart pulsates strongly and rhythmically, corresponding to the pulse at the wrist. The pulsation can be perceived easily all over it, the lower half moving to the left during systole.

'The horizontal level is continually in movement. Apart from the respiratory change of position, there are undulations which are to some extent synchronous with the contraction of the heart; but this rhythm is disturbed by irregular waves which pass over the surface at the same time. When the patient holds his breath, one can see clearly the level rising at each cardiac contraction. The slightest movements of the thoracic floor show themselves on the surface level. This remains horizontal when the patient bends over to the right side or to the left. On percussion of the thorax the undulations above described become more pronounced, and they attain the height of ten centimetres when the patient is violently shaken. They may be compared to the oscillatory movements seen in a vessel filled with liquid when it is sharply agitated.

'The photograph reproduced in the accompanying illustration was taken with the patient sitting down, leaning his back against the case containing the photographic plate. The tube is 15 centimetres distant from the sternum, at the height of the surface level. The photograph reproduces very closely the description given of the image on the screen, but, of course, without the phenomena of movement.

'On examination of the patient lying down on his left side, the darker shadow is again seen undermost, but it now extends from the apex of the lungs to the diaphragm, and shows neither pulsatory nor respiratory movements. The median part of the left half of the diaphragm is visible in this position. It is obviously depressed, and does not appear to be moving distinctly. The shadow of the heart subsides to a slight extent into the left half of the thorax.

'We may infer from these appearances that the right lung is diseased in nearly its whole extent, while on the left side there is pyopneumothorax. The comparative opacity of the right lung is to be attributed to compression, infiltration and thickening of the pleura; the dark apex is characteristic of tuberculosis.

'The shadow in the upper part of the left pleural cavity is due to the adherent contracted apex of the left lung. Below it there is air, hence the marked transparency of this part as seen on the screen and in the photograph. The inky and lowest shadow is caused by liquid which amounts—judging from its height—to

several litres. It is probably sero-purulent in character. The heart is enlarged and shifted into the right half of the thorax ; the pericardium appears to envelop it very closely. Its apex is directed to the left, and is immersed in the empyema fluid. The pulsation is strong and quick.

'These, of course, are all pathological changes which could be discovered by ordinary physical methods of examination.

'Although the Röntgen screen shows the level of the effusion two fingers' breadth higher than the limit obtained by percussion, this is very frequently observed, so that the contradiction in this repect is more apparent than real.

'The other observations on the Röntgen screen are, however, of the greatest interest. I mean the phenomena of motion ; first, the respiratory movements.

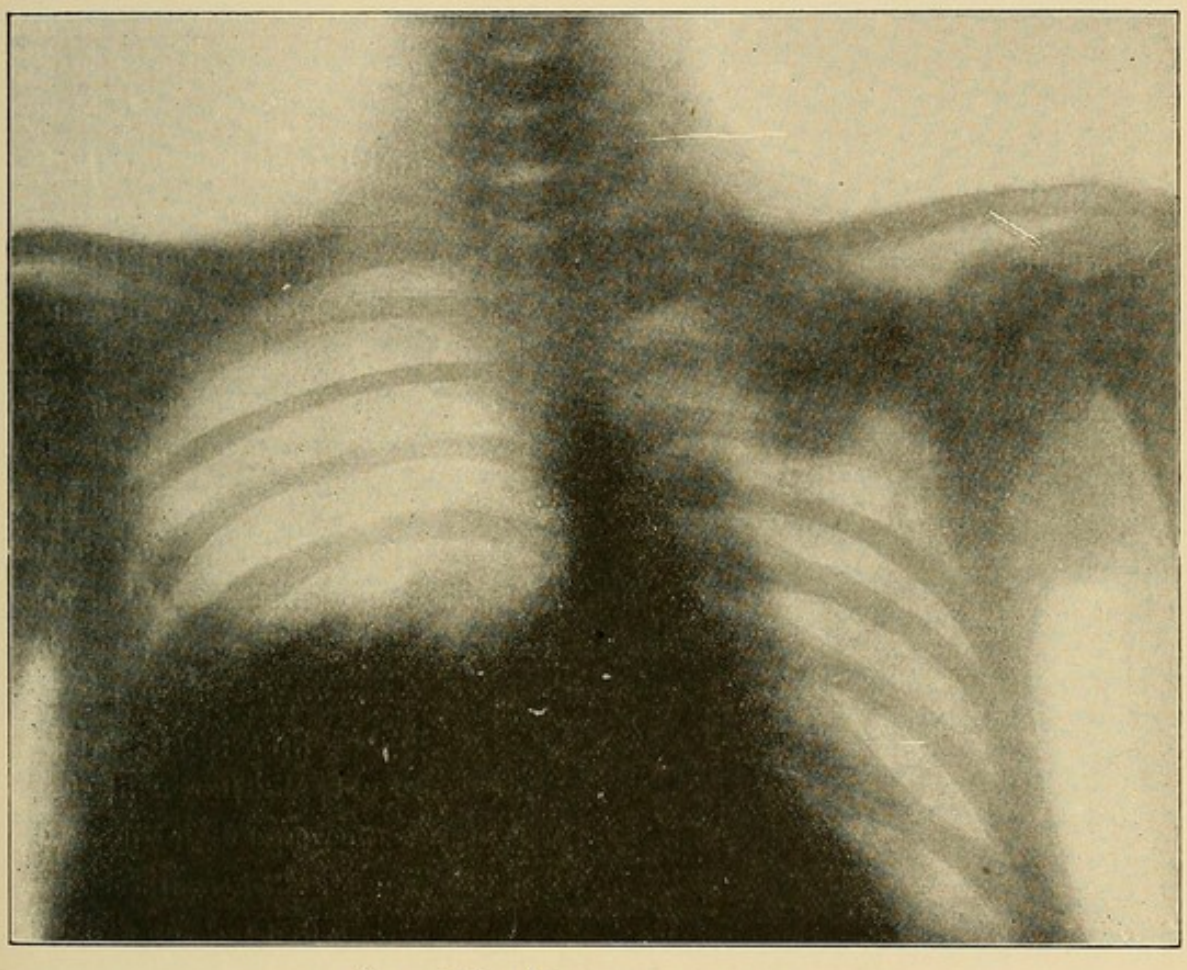


FIG. 165.—PYOPNEUMOTHORAX.

There is an inspiratory ascending and an expiratory descending movement of the surface level.

'Various *explanations* of these phenomena have been suggested. I am disposed to think that the inspiratory dilatation of the right pleural cavity, by raising the pressure in the abdomen, tends to raise the paralytic depressed left half of the diaphragm.

'The second phenomenon is the *pulsatory* movement of the level. There is a wave moving from the heart to the left during its systolic contraction (*empyema pulsans*).

'The reason why the pulsation is not perceptible on the outside, either to the eye or the finger, may possibly be that the air-pressure in the pleural cavity is

not sufficiently high. The elasticity of the air enables it to yield to the systolic shock of the liquid, and therefore the wall of the thorax is not concussed, in spite of the strong action of the heart; further, the wall may be too rigid, or the pleura costalis too much thickened.

'The *third kind* of movements depend upon outside influences—the varying position of the patient, sudden movements, communicated vibrations, and particularly the great amplitude of the oscillations seen when the patient is violently shaken. We are thus enabled not only to hear, but also to see, the *succussio Hippocratis*.'

Mr. J. F. Halls Dalby, M.B.,* has made some notes on the radiographic appearance of pleurisy. In one case, without effusion of fluid, in quiet respiration the excursion of the diaphragm was $\frac{5}{8}$ inch on the right, as against $\frac{3}{8}$ inch on the other, or pleuritic side. On deep inspiration the movements are $\frac{3}{4}$ inch on the affected against $1\frac{7}{8}$ inch on the affected side. He arrives at the following conclusions: (1) That the level of the fluid changes with the position of the gradient unless (*a*) the quantity of the fluid be great, or (*b*) the fluid be encysted by adhesions; (2) that a purulent effusion yields a shadow of greater density than a sero-fibrinous effusion; (3) that the shadow is homogeneous, and in the case of serous effusion gradually increases in density from above downwards; (4) that, however far the heart be displaced to the right, in most cases little alteration takes place in the position of the apex relatively to the base; (5) that, other conditions being equal, the heart is displaced more when the effusion is left-sided; and (6) that a somewhat triangular shadow, not normally visible, above and continuous with the shadow of the heart and pericardium, is cast by the mediastinum, which is displaced by the lateral pressure towards the healthy side of the thorax.

Mr. Dalby quotes a paper by Professors Bergonié and Carrière† to show that in the majority of instances the results of radiographic examination coincide with those of percussion. Out of eleven cases, the French observers found in four the upper limits of percussion dulness and of shadow exactly coincided, and in two no results were stated. Their conclusion that the convex upper curve is formed by hyperæmic or atelectatic lung is disputed by Dalby, who agrees with Walsham and Williams that oftentimes a lung is compressed on the inner side of an effusion with a sickle-shaped edge.

* *Lancet*, February 27, 1904.

† *Archives d'Électricité Médicale*, July 15, 1896.

Dalby ascertained the relative radiographic density of serous and purulent fluids by taking a photograph of a spot of each fluid side by side on a glass plate, and by comparing two test-tubes similarly charged on the screen. In each experiment the purulent casts a much denser shadow than the serous effusion.

The Indications for Pulmonary Operation.

An important paper on this subject has been published by Dr. Rudolf Riegner.* He gives as indications for surgical interfence—

1. Acute and chronic abscesses.
2. Acute and subacute gangrene.
3. Chronic gangrene.
4. Bronchiectasis.
5. Tuberculosis.

Illustrative cases are added, especially one in which a skiagram showed a circumscribed patch of gangrene at the angle of the left scapula. The cavity was drained, and recovery followed.

The writer disclaims any personal experience of the surgery of tuberculous cavities, but mentions that no case has been reported in which the opening of a cavity has cured phthisis. Lowson and Tupper claim to have cured two cases by resection of the whole pulmonary apex with the contained cavities. Quincke and Spengler have noted improvement after resection of ribs and collapse of walls of cavity, without incision into latter. It should be borne in mind that every operation in phthisis is apt to be followed by an acute dissemination of bacilli.

MEDICAL DIAGNOSIS BY RÖNTGEN RAYS.

SPECIALLY CONTRIBUTED BY A. W. CRANE, M.D. (U. OF M.), KALAMAZOO, MICHIGAN, U.S.A., MEMBER OF RÖNTGEN SOCIETY, LONDON.

Thorax and Abdomen.

For the purposes of medical diagnosis, soft tissues of small density must be studied. This demands *x*-rays generated by powerful currents in tubes of low vacuum.

* *Deutsche Med. Woch.*, July 17, 1904, p. 515.

The Thorax is a region singularly adapted to an *x*-ray examination. No other soft tissues of the body are distinguished by such differences in density as the thoracic viscera. The fluorescent screen is here incomparably superior to the dry plate, because the constant movements of the heart, lung tissues, and diaphragm, which serve only to blur outlines or erase details upon the plate, become factors of importance upon the screen. It is a great advantage to use a screen of sufficient size to receive the image of the entire chest. Relations, movements, and details of the shadow-image are thereby more accurately and quickly appreciated. All light must be excluded from the room, and the retina rested in darkness, or the most brilliant illumination of the screen will appear like a gas-jet in daytime. The stereoscopic fluoroscope is the ultimate ideal of clinical radioscopy.

Normal appearances must be familiar to one who would appreciate the radioscopic signs of disease upon the screen. The lungs are clear spaces which perceptibly darken and lighten with deep inspirations. This respiratory change is most marked in the lower half of the lungs. The pleuron is denoted by a delicate tracery of shadows following the outlines of the heart and great vessels. The diaphragm can be seen rising and falling with each breath. During quiet breathing it moves from 1 to 2 cm. The left side averages one interspace lower than the right.

The median line is marked by the broad shadow of the spinal column. To the lower left side, the shadow of the heart projects in bold relief, the apex lying at the middle of the left diaphragm, and the base lying at the middle point of the thorax. To the right, a narrow strip of the right ventricle and auricle may be seen. The contraction of the left ventricle with the peculiar retracting movement of the apex may be clearly observed. The pulsations of the right heart and of either auricle may also be distinguished. If the tube be placed at the level of the diaphragm, the clear pericardial space between apex and diaphragm may be seen during deep inspiration. The aortic arch and pulmonary vessels occupy the space between the base of the heart and the sternal end of the clavicles.

The heart is best studied from the front, and the great vessels from the back of the chest. It is often an advantage to turn the patient slowly around behind the screen, and to make a careful observation from the side with the patient's arms upraised. In

pulmonary and pleural affections, the patient should be examined while lying down as well as while standing.

Appearances in disease result from two simple factors—shadow and motion. The relation of these factors to disease may be most clearly and compactly expressed in tabular form. See Charts I., II. and III.

An *x*-ray examination of the chest should be preceded by the ordinary physical examination. In that way the one will supplement and correct the other. But the information elicited by palpation, percussion, and auscultation is not in each case co-extensive with the information gained by the fluoroscope, skiameter,* and radiograph.

By palpation we may feel the rhonchi, the friction fremitus, and the vocal fremitus. The rhonchi and the friction fremitus denote conditions which give no sign in radioscopy. The vocal fremitus is increased over consolidated areas, and decreased over emphysematous areas. In this it agrees exactly with radioscopic signs. If, however, we draw the conclusion that whenever the vocal fremitus is increased we should find an increased density in the fluoroscopic shadow, and *vice versa*, we shall be disappointed. In pleuritic effusions we find the vocal fremitus decreased or absent, but we find the floroscopic shadow dense and unmistakable. The same is true of pleuritic thickenings, of filled cavities, and of consolidations with occlusion of the large bronchi. Moreover, the vocal fermitus is increased over dense-walled cavities, which would give a ringed area of light reflex upon the fluoroscopic screen. In these states it could be said that the results of palpation are not parallel with those of radioscopy. It is simply that the narrow limits of palpation must be kept in mind, and only its positive data considered.

Between percussion and radioscopy the comparison is closer. The same factors which determine the *x*-ray shadows also determine the character of the percussion-note. The results of percussion and radioscopy must agree, except that radioscopy is the more delicate and precise method. We may express the relations of percussion to radioscopy by a diagram on page 346.

* The skiameter is an instrument devised by the author to measure the intensity of shadows and linear distances. It is made of strips of tinfoil so graded as to give a scale of partial shadows. The principle applied is the obliteration of one partial shadow by another overlying shadow. It is fully described in the *Philadelphia Monthly Medical Journal* of March, 1899; also in the *Philadelphia Medical Journal* of January 6, 1900, vol. v., No. I.

CHART I.

- **Lung and pleural sac**
  - **Increased transparency**
    - General ... Bright or light reflex... → Pneumothorax. / Emphysema. / Compensatory emphysema.
    - Local ... Bright or light reflex... → Empty cavities. / Pneumothorax. / Bronchiectasis. / Local emphysema.
  - **Decreased transparency**
    - General ...
      - Light shadow ... ... → Generalized pleural thickening. / Congestion.
      - Dark shadow ... ... → Œdema. / Cirrhosis.
      - Black shadow ... ... → Effusion to apex. / Total consolidation.
    - Local ...
      - Light shadow ... ... → Infiltration. / Thickened pleura. / Atelectasis.
      - Dark shadow ... ... → Partial consolidation. / Small filled cavities. / Pleuritic exudates. / Small tumours. / Infarcts.
      - Black shadow ... ... → Consolidation. / Pleuritic effusions. / Gangrene. / Large filled abscess. / Large tumour. / Large hydatid cyst.
  - **Motion**
    - General ... Changes in density ... During respiration.
    - Local ... Changes in form ... → Of half-filled cavities. / Line of thickened pleura. / Effusions.

CHART II.

- **Diaphragm**
  - **Visibility**
    - Increased ... ... → Inspiration. / Emphysema. / Pneumothorax.
    - Decreased ... → Expiration. / Œdema. / Congestion of the lower lobe. / Consolidation of lower lobe. / Thickened pleura at base. / Pleuritic effusion or exudate.
  - **Position**
    - Low... ... ... → Emphysema. / Asthma.
    - High ... ... → Cirrhosis. / Tuberculosis, etc.
    - (Difference of the two sides to be noted.)
  - **Form**
    - Arched ... ... When high.
    - Flat... ... ... When low.
    - Irregular . ... → In diaphragmatic hernia. / Hepatic abscess beneath diaphragm.
    - (Difference of the two sides to be noted.)
  - **Motion**
    - Ordinary respiration ... ... → General range
      - Restricted → Tuberculosis, etc. / Pleurisy.
      - Exaggerated → Compensatory emphysema.
    - Forced respiration → General range
      - Restricted → Tuberculosis, etc. / Pleurisy.
      - Exaggerated → Compensatory emphysema.
    - Forced respiration → Upper half
      - Restricted → Emphysema. / Asthma. / Pleurisy.
      - Exaggerated → Compensatory emphysema.
    - Forced respiration → Lower half
      - Restricted → Tuberculosis, etc. / Pleurisy.
      - Exaggerated → Compensatory emphysema.

CHART III.

- **Heart**
  - **Visibility**
    - Increased
      - By deep inspiration.
      - By emphysema.
      - By cardiac hypertrophy.
      - By cardiac dilatation.
    - Decreased
      - By deep expiration.
      - By adjacent pulmonary shadows.
      - By œdema or congestion of lung.
      - By generalized thickening of pleura.
      - By empyema or effusion.
      - By very thick chest walls.
  - **Displacement**
    - To left
      - Cirrhosis of left lung.
      - Empyema or effusion on right side.
      - Tumour or aneurism on left side.
    - To right
      - Cirrhosis of right lung.
      - Empyema or effusion on left side.
      - Tumour or aneurism on left side.
    - Downward
      - Hypertrophy.
      - Aortic aneurism.
    - Transposition
      - Congenital.
  - **Size**
    - Increased
      - Hypertrophy.
      - Dilatation.
      - Pericardial effusion (apparent).
      - Cardiac aneurism.
    - Decreased
      - Senile atrophy.
      - Congenital lack of development.
  - **Form**
    - Irregular
      - Aneurism of auricle or ventricle.
      - Dilatation of single auricle or ventricle.
    - Rounded
      - Senile atrophy.
      - General dilatation.
      - Pericardial effusion.
  - **Movements**
    - Pulsation of auricles
      - Increased
        - Hypertrophy.
        - Auricular dilatation.
        - Auricular aneurism.
        - Valvular disease.
      - Decreased
        - Old age.
        - Debility.
    - Pulsation of ventricles
      - Apex beat
        - Increased
          - Hypertrophy.
          - Fevers.
          - Certain diseases and drugs.
        - Decreased
          - Dilatation.
          - Pericardial effusion.
      - Pulsation of right ventricle
        - Increased
          - Hypertrophy and dilatation of right ventricle.
        - Decreased
          - Senile atrophy.
          - Lack of development.
    - Heart reflex
      - Elicited by rubbing skin over heart by a blunt instrument.

The field of auscultation is larger in many directions than that of pulmonary radioscopy. The sounds of the heart, affections of the bronchial tubes denoted by râles, and inflammations of the pleura denoted by friction sounds, are beyond the province of the *x*-rays.

Differential Diagnosis in radioscopy is a matter of reflex, shadow, and motion. *A bright reflex* indicates a large, empty cavity or a large pneumothorax. If it be a cavity, the bright reflex may be centrally located and wholly surrounded by a dark or black shadow, or it may be peripherally located and only partly surrounded. The limits of a large cavity are never sharply marked unless on the lower side, when partly filled with sputum. If it

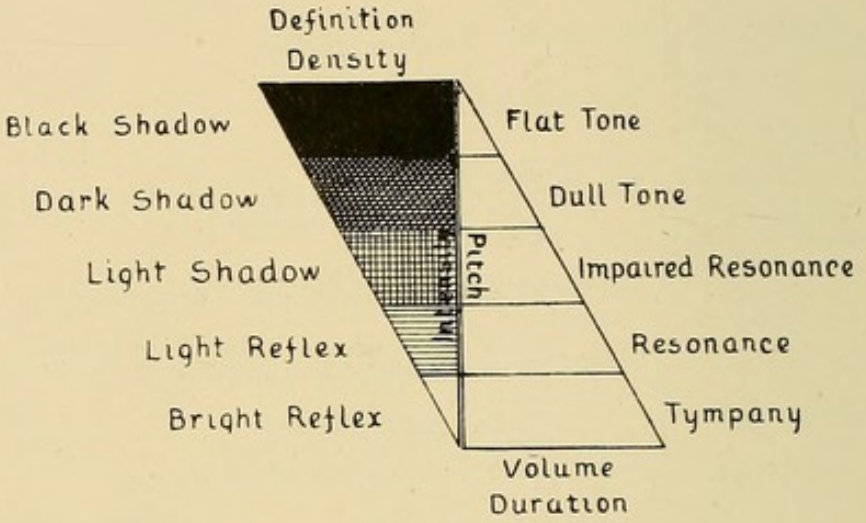


FIG. 166.

be a pneumothorax, the bright reflex is peripherally located, and usually larger than in the case of cavity. If it exist without the presence of pulmonary shadows, the diagnosis is clear, because cavities are always associated with some consolidation. If, however, consolidation does occur with pneumothorax, the outline of the lung will be observable. A local pneumothorax from bronchial communication with the pleural sac, and from circumscribing adhesions, could not be distinguished from a peripheral cavity, especially if it occurred over the front or back area. Its position, however, front or back, could be determined by observing from which side it could be most plainly seen. The closer any object lies to the fluoroscopic screen the clearer the image.

A light reflex indicates a small cavity, a large cavity nearly full, a small pneumothorax, a greatly dilated bronchus, or an

emphysema. If it be a small cavity, it will lie in the midst of a dark or black shadow, and may be called a light reflex, because it is in contrast with its surroundings. It may be encircled by a narrow ring of dark or black shadow if the walls are calcified. This is a healing process that can occur in a small cavity only. Why the calcareous thickening of a spherical cavity will cast the shadow of a ring is easily seen from Fig. 111. The *x*-rays traverse more substance in passing through the edges of the rim than in passing through the middle. This difference is the difference between the lengths *ab* and *cd*.

If it be a large cavity nearly full, the light reflex will rest upon a dark or black circumscribed shadow, unless the surrounding consolidation is so dense as to obscure the shadows of the mass of sputum. If the patient be re-examined on the table, the cavity

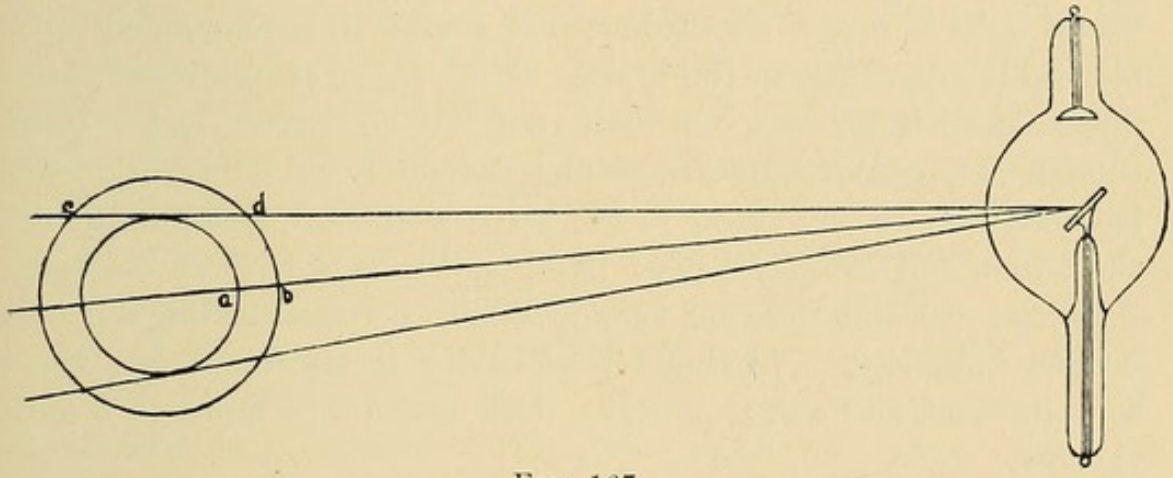


FIG. 167.

may empty and become a large, bright reflex, or it may nearly disappear because the mass of sputum has come to lie in line with the empty space. If a faint reflex be observed without the presence of pulmonary shadows, it is likely due to a dilated tube in bronchiectasis. A diluted bronchus with consolidation could not be distinguished from a small cavity, unless a longitudinal form were to give a clue. A small pneumothorax, allowing a layer of air to surround the lung, would give a general light reflex, which would be indistinguishable from a true emphysema. In both cases the movements of the diaphragm would be restricted, its line low and and its form flattened. But an emphysema is bilateral, unless there is some disease of one side to produce a compensatory condition on the other side. In the case of pneumothorax, the disease would be on the same side as the general light reflex. Hydro-pneumothorax

or pyopneumothorax would give the same images as pneumothorax, except that we would have the dense shadows of effusions at the base. By changing the position of the patient, the relative position of the shadows and light reflexes would be changed.

A light shadow may mean an infiltration, a congestion, an atelectasis, or a thickened pleura. Between a tuberculous infiltration, a simple focal congestion, and an atelectatic area, there is no shadow-distinction. A thickening of the pleura may sometimes be differentiated from these three if its shadow be plainly visible, say from the front, and nearly or quite invisible from the back. But an infiltration or small consolidation lying close to one side would simulate this appearance.

A dark shadow indicates a partial consolidation, a small tumour, an infarct, or a cirrhosis. In the case of œdema the dark shadow is diffuse and of even density; a general cirrhotic lung would give a less even shadow, and would be accompanied by a marked displacement of the heart. Other physical conditions easily differentiate these two. A focal cirrhosis, an infarct, and a small tumour may give shadows of similar character, but a cirrhotic focus is most likely to be located in the apex, a tumour most likely near the hilum, and an infarct most likely in the periphery of the lung. A partial consolidation has very indefinite borders shading out into normal lung tissue. A small filled cavity is associated with some consolidation, and will appear as a dark spot in the midst of a dark shadow.

A black shadow may result from consolidation, gangrene, large filled abscesses or cavities, large tumours, large hydatid cysts, and pleuritic effusions. The last is distinguished by lying at the base of the thoracic cavity, by obscuring the diaphragm-line, by a more or less level upper border, and by being shifted when the patient's position is changed. The other conditions may not be separable by an *x*-ray examination, although their boundaries may be mapped out.

The diaphragm cannot be disregarded in radioscopy of the lungs. Its visibility, position, form, and motion are factors of the highest importance in estimating the extent and severity of a pulmonary disability. It is the vital barometer of the lungs, and may give the first signs of a coming storm.

Its visibility depends upon the contrast which its heavy shadow makes with the thin shadow of the lung. It is a dome of muscle

which rests upon the liver on the right, and is visible across the whole extent. On the left it rests upon the stomach, and is visible across the outer half, the inner half being obstructed by the shadow of the heart. In forced inspiration, however, the diaphragm becomes also visible below the heart. The shadow-line of the diaphragm becomes more distinct in forced inspiration because the lungs contain more air and because the diaphragm, being flatter, interposes more tissue in the path of the rays. Conversely, the diaphragm-lines become less distinct in forced expiration, because the lungs contain less air, and because the diaphragmatic dome, being more arched, interposes less tissue in the path of the rays.

The diaphragm becomes very distinct when there is an emphysema or pneumothorax without effusion. But emphysema is either bilateral or else compensatory and attended by disease on the opposite side. On the other hand, pneumothorax would show the shadows of a partially or wholly collapsed lung. The diaphragm may become indistinct in œdema, hypostatic congestion, partial consolidation of the lower lobes, or thickened pleura around the base. But in œdema there is a general shadow of even density. In congestion, partial consolidation, and thickened pleura at the base, the upper areas of the lung may be normal. But these three are not separable on physical grounds alone.

The diaphragm becomes invisible when there is an effusion or a consolidation of the lower lobe. But with effusion the outline of the shadow may be easily shifted, and when the patient is placed upon the examining table with the head lowered, the diaphragm comes into view. If the entire lung is consolidated, or if the effusion is encapsulated or reaches to the apex, the conditions may be indistinguishable without the use of the hypodermic needle. If the right lung is affected by tuberculosis, the diaphragm on that side will be higher than usual, while on the left it will be lower than usual, on account of the compensatory changes. In emphysema the diaphragm lies very low, in cirrhosis very high.

The position of the diaphragm largely determines the form. It is flattened when low, and arched when high. In diaphragmatic hernia the form is irregular.

The motion of the diaphragm is of great concern. We may recognise the range of movement in ordinary and in forced respiration. By marking the middle point in ordinary respiration, we may observe the upper and the lower half of a forced respiration.

As a rule, in health, the range of ordinary and forced respiration is slightly greater on the right side than on the left. A restriction in the range of motion is a sign of some disablement. It is most likely to mean tuberculosis, pneumonia, or pleurisy. But it may mean almost any affection of the lungs or mediastinum. In true emphysema and pneumothorax, the respiratory movement is restricted in its upper half. In compensatory emphysema the respiratory movement is increased in both upper and lower half. This is important, because a compensatory emphysema on one side means an impairment of the lung on the opposite side. It may, however, in rare cases be an old trouble from which the patient has recovered. A very marked restriction in the motion of the diaphragm or its immobilization is a grave sign. Pleurisy, especially diaphragmatic pleurisy, forms an apparent exception. However, if the patient be encouraged, the diaphragm can be moved, although pain is the result.

When, in addition to the shadow-free lung, we find a natural movement of the diaphragm, we may feel assured that, even though tubercle bacilli are present in the sputum, the lung substance is not yet seriously affected. Such cases may be laryngeal or bronchial.

The heart may be outlined by the *x*-ray with a precision unequalled by any other method. Hypertrophy, dilatation or aneurism of either ventricle or of either auricle, may be perceived and measured. In pronounced cases of distension of the right ventricle, the apex may be tilted upward so that a space is left between the tip of the heart and the diaphragm. In dilatation involving the left ventricle, the apex beat becomes nearly indistinguishable. In rare cases a valve can be seen when it becomes calcified.

A vigorous cardiac reflex indicates a good tone of the heart muscle. This reflex is worthy of careful clinical study.

In examining the heart, keep in mind its visibility, position, size, form, and movements.

Pericarditis with effusion may be strikingly demonstrated by screen or dry plate. The pericardial space between heart and diaphragm is obliterated, even by a very small effusion. A large effusion will show the faint outline of the heart within a large ring. The distended pericardium gives a ringed appearance, for the same reason that a thick-walled cavity does, and, furthermore, for the reason that the pleura and lungs are pushed aside, thus forming

a dense wall on the two sides, but not on front and back. An aspirating needle is clearly visible behind the screen, and may be accurately guided into the distended pericardial sac.

Aneurism of the thoracic aorta has afforded brilliant examples of the value of the *x*-ray. Aneurism is distinguished from mediastinal tumour chiefly by the presence of a pulsation. If this can be seen to be expansile, the diagnosis is certain. But pulsations may be transmitted to tumours which lie against heart or aorta. The certainty with which long needles may be passed into an aneurism while in view beneath the fluorescent screen may aid in the treatment of this affection.

A calcification of the aorta wall may sometimes be delineated upon the dry plate.

The Abdominal Viscera vary from one another so slightly in density that differentiation by the *x*-ray is difficult and incomplete. But biliary calculi, and stones in the kidneys, ureters, and bladder, dermoid cysts containing bone or teeth, and the bones of a fœtus, may be successfully portrayed. Here, as in the thorax, the lowest vacuum tube which will give a good penetration must be used, so as to obtain the greatest possible contrast between tissues of small densities. The dry plate rather than the screen should usually be employed, excepting in the case of restless children. The stomach and bowels should be emptied, and then distended with gas and air respectively. The abdomen should be tightly bandaged to prevent the respiratory movements from blurring or erasing delicate details.

The stomach, in a thin abdomen, will show as a clear space with hazy outlines, below the left diaphragm. An hour-glass contraction may be perceived, and an enteroptosis may be distinguished from a simple dilatation. The distended stomach extends over the left border and half of the lower edge of the liver, and also over a portion of the outer border of the left kidney. The distended *cæcum* and ascending *colon* are usually very well marked, and overlie the outer border of the right kidney and a small portion of the lower edge of the liver. Thus, the *liver* is sometimes nearly outlined, and a small margin of each *kidney* may occasionally show upon the plate. The distended *rectum* and *sigmoid flexure* are not difficult to bring out, and the *psoas muscles* are nearly always visible upon a good plate. The ribs, vertebræ, and ilium offer no especial difficulties.

The fluorescent screen may be used to advantage in examining

the stomach. If a patient, while standing behind the screen, will drink, in quick succession, a drachm each of potassium, bicarbonate and tartaric acid, dissolved in separate glasses, the stomach may be beautifully demonstrated. Instead of distending the stomach with gas, an emulsion of the subnitrate of bismuth may be swallowed; or a stomach-tube containing a metallic chain or coil of wire may be passed and allowed to lie along the greater curvature; or a large capsule of bismuth subnitrate may be swallowed to mark the lowest point of the stomach. The latter may be used to good advantage in connection with the gaseous distension. A. W. C.

Abdomen.

The stomach may be outlined by means of bismuth emulsion, or by bismuth capsules, or by a long flexible bougie containing a slip of metal, and passed into the organ. The position of the opaque object may be detected on the screen. In pyloric stenosis a capsule generally remains for several days in the stomach (Lévy-Dorn and Boas).

Murphy's buttons and other foreign bodies have often been detected in the abdomen, especially in children, as well as calculi in various organs. Alteration in shape and size of liver, spleen, and kidneys may sometimes be detected; and stricture of intestines may sometimes be revealed by injecting through the rectum an emulsion of bismuth, and then taking a radiogram.

Practical Conclusions.

To sum up the applications of Röntgen rays to clinical medicine: First of all, we find that satisfactory results are confined chiefly to the thorax, although now and then useful information has been obtained from the abdomen. Secondly, in the lungs we can sometimes get early information as to tubercle, which may not be disclosed by ordinary means of physical or bacteriological examination, and effusion of fluid in pleurisy may be accurately estimated, as well as in pericarditis and in various non-inflammatory local dropsies. As to the heart and large vessels, enlargements and displacements can be readily demonstrated, together with thoracic aneurism. Such alterations can be detected when cloaked from ordinary examination by emphysema of the lung. The results of the Schott plan of treatment of heart diseases can also be followed.

One important point is the possibility of localizing patches of tubercular consolidations and cavities in the lung substance. Hitherto one of the chief obstacles to the progress of lung surgery has been the difficulty of exact localization. Thus, it not infrequently happens that the physical signs point to the presence of a cavity where that particular lesion, in point of fact, does not exist. If this diagnosis, then, could be cleared up definitely by a radiogram or by the fluorescent screen, the hands of the surgeon would be considerably strengthened in dealing with individual cases. It is hardly needful to remind the reader that the fact of a deep consolidation lying beneath healthy lung renders it extremely difficult or impossible to diagnose the trouble by percussion and auscultation.

A clot in the brain, especially if large in size and near the surface, and patches of softening, may at times be radiographed.

V. OTHER MEDICAL POINTS.

The Diagnosis between Gout and Rheumatoid Arthritis.

In May, 1897, Messieurs Oudin and Barthélemy showed a series of Röntgen photographs of the hands and feet of patients affected with gout and with rheumatoid arthritis.* Normally the articular cartilages are transparent, and the dark shadows of the bones are separated by a clear band from 1 to 3 millimetres in width, a condition that is maintained to the end of life in the healthy subject. In gout (Fig. 133) these clear spaces are unaffected, but the disease is characterized by tophi, which appear as light patches on the denser bone. In rheumatoid arthritis, however, the clear spaces disappear, even in young subjects, and that fact, together with the bony outgrowth and deformity, furnishes diagnostic signs by the Röntgen methods (Fig. 134).

Enlargement of the axillary glands has been seen in breast cancer.

Calcification of Arteries.

As might be expected, a radiographic record can often be obtained of calcification in arteries, whether primary of the middle coats or secondary of the inner.

* *La France Médicale*, June 4, 1897.

Makrodactyly.

Dr. W. Mafeig Jones* has published a case of this condition in a young man of twenty. A radiogram of the affected foot shows that the bones of the great toe were not enlarged, but that there was an exostosis on the inner head of the first metatarsal bone, and another on the base of the distal phalanx of the big toe. The fifth metatarsal was not enlarged, and the second only slightly; but the third and fourth were much hypertrophied, especially their distal ends. With the exception of the great toe, all the phalanges were enlarged, especially those of the third toe, and all showed exostoses.

Hæmophilia.

Dr. F. J. Clendinnen† has published notes of a case, with accompanying radiogram, of hæmophilia. He was called to see a male child, eleven weeks old, for supposed injury to the right hip. On examination the hip was found to be much swollen, semiflexed on the abdomen, and painful. A radiogram showed the bones intact, but a general opacity in and around the joint, and the head of the femur separated from the base of the acetabular cavity. From the appearances thus presented, hæmorrhage into the joint was diagnosed. A few days later the child passed tarry motions. Two days later the left shoulder became swollen, and later the right. The rays showed that both elbows, which were not swollen, shared in the hæmophilic process. There was no family history of the complaint.

Joint Affections in Locomotor Ataxy.

The pathology of this condition has been illustrated in a case reported by M. E. Dupré and A. Devaux.‡

A man aged fifty-four, under treatment for well-marked locomotor ataxy. In 1890 lightning pains occurred, varied by painless enlargement of both knees in 1897. The radiogram showed that the articular enlargement and deformity were due, not so much to lesion of the articular extremity of the bone as to changes in their relations to each other, to synovial effusion, and to osteo-fibrous growths within the capsules of the joint. The femoral condyles

* *Intercolonial Medical Journal of Australasia*, August 20, 1901, p. 389.

† *Quarterly Medical Journal*, February, 1900, p. 182.

‡ *Nouvelle Iconographie de la Salpêtrière*, September to October, p. 498.

of the knee-caps were normal, and the head of the left tibia alone was enlarged. On both sides the knee-cap was displaced forwards, and the femur backwards.*

Gilbert has also shown that the bony swelling in such cases, which is believed to be extremely large, is really slight. The ligaments, tendons, and soft parts generally, are studded with bony islets, independent of each other, and separate from the articulation.

In the case above described, the inability to walk was due more to the joint affection than to ataxy itself.

Acromegaly.

An interesting case of acromegaly in the father, and infantile myxœdema in a child, is reported by Drs. F. M. Pope and Astley Clarke.†

The general enlargement of the bones of the hand is well shown. It is interesting to note that the epiphyses at the distal ends of the metacarpal appear to have escaped the hyperplasia.

Béclère‡ considers that by revealing the presence of irregular thickening of the cranial parietes, especially hypertrophy of the sella turcica, the *x*-rays will prove of valuable assistance in the diagnosis of acromegaly.

Diagnosis of Œsophageal Diverticulum.

Victor Blum records (*Wien. Klin. Woch.*, March 15, 1900)§ a case where a diverticulum of the œsophagus was diagnosed, after œsophagoscopy had failed. The patient had been subject to obscure symptoms of œsophageal disturbance with eructation of food. A tube filled with mercury and closed at one end was introduced into the œsophagus, and arrested in its course before it reached the stomach; *x*-ray examination then showed the tube lying alongside the spine, about 10 inches below the level of the teeth, in such a fashion that a diverticulum was suggested. A sound filled with bismuth was then introduced with the aid of the fluoroscope, and the presence of the diverticulum made certain. On

* For illustration, see *Medical Review*, vol. iii., No. 26, November, 1900, p. 668.

† *British Medical Journal*, December 1, 1900, p. 1563.

‡ *La Presse Médicale*, December 9, 1903, p. 845.

§ *British Medical Journal*, Epitome, June 9, 1900, p. 90.

withdrawing the tube and sound it was possible to pass an india-rubber bag like a toy balloon filled with a solution of potassium bromide, which is opaque to *x*-rays, into the diverticulum, and in this way the exact position, form, and size of the latter were ascertained. Blum considers this the best method for actually diagnosing œsophageal diverticula.

Stricture of Œsophagus.

A method of diagnosing œsophageal stricture has been well illustrated by Mr. Thurstan Holland* in a radiogram showing a dense oval pouch, taken after the patient had swallowed 2 ounces of strong bismuth mixture.

Stricture of the gullet may be demonstrated on the screen by the stoppage of a metallic sound, or of a capsule filled with bismuth or some other substance opaque to the rays. A radiogram (taken by Dr. Pilcher) is published by Butler,† of an œsophageal stricture accurately outlined in a patient to whom 3 drachms of bismuth subnitrate, in a semi-fluid paste, were administered immediately before exposure. Diverticula of the œsophagus may be detected in the same way.

VI. ACTION OF THE FOCUS TUBE UPON THE SKIN AND DEEPER STRUCTURES.

Soon after the Röntgen rays came into general use, as everyone knows, cases of resulting injury to the skin were reported. This ill-effect was usually spoken of as '*x*-ray dermatitis,' but the present writer, in a paper‡ read before the Dermatological Society of Great Britain and Ireland in July, 1897, ventured to suggest the non-committal name of 'focus-tube dermatitis.' By either term is meant an inflammation of the skin following one or more exposures to a focus tube in action. The damage may be fleeting, nothing more than a slight reddening of the skin, with sudden onset and rapid disappearance, or the hairs of the affected part may fall out painlessly. On the other hand, it may be severe, coming on from

* *Archives of the Röntgen Ray*, November, 1904.

† 'Diagnostics of Internal Medicine,' Dr. G. R. Butler, 2nd ed., p. 714. Appleton, London, 1905.

‡ See *Transactions Dermat. Society of Great Britain and Ireland*, vol. iii., p. 137.

a few days to three weeks after the exposure; the epidermis may peel off, or the underlying tissues may slough away, and leave an obstinate ulcer that takes months to heal.

A large number of instances of severe damage have been recorded.

* The existence of cause and effect in this condition has been established both by the large number of recorded cases and by certain experimental observations. Making every allowance, however, for cases that are not recognised and for the far larger number that are not recorded, it nevertheless seems evident that the percentage of cases of dermatitis following exposure to the focus tube must be small. Of late there has been a marked diminution of reported cases, a fact probably explained by the general shortening of exposures and by the greater care that is now exercised to avoid unnecessary exposure.

There is nothing specific about the inflammation of the skin, nothing in its appearance that would proclaim it as due to the focus tube. It is a symptom of a remote exciting cause, and resembles the dermatitis set up by a number of other external irritants, such as exposure to a hot sun, to a furnace, or to the action of a caustic alkali. The question before us in this particular case is the nature of the irritant peculiar to the focus tube.

If a multitude of persons be exposed to a hot sun, perhaps one out of a million will develop a severe dermatitis, resembling that set up by the focus tube. In both instances there is a distinct, if imperfectly understood, *causa causans;* but something more is needed to account for the phenomenon of individual selection, and that we may express by the convenient term 'susceptibility.' In this way the extremely small proportion of persons attacked by focus-tube dermatitis may be so far explained: many are exposed to the irritant, but few are abnormally susceptible.

Other contributing factors are, seemingly, the nearness of the focus tube to the skin, the resistance of the tube, and the duration and frequency of exposure. These assumptions, in addition to a certain amount of evidence to be quoted forthwith, may be supported by the analogy of a hand held near a hot furnace: the nearer the hand to the fire and the oftener and the longer it be placed there, the greater will be the resulting damage. The

* The next few pages are from a paper read by the author before the Röntgen Society of London to introduce a discussion, December 6, 1898.

proposition that the injurious effects of the focus tube are inversely to the distance of the tube from the skin and the length and frequency of exposure is supported by the following evidence:

1. Close proximity of tube and an exposure of ten minutes or a quarter of an hour is adopted in order to produce therapeutic or intentional dermatitis.

2. In most of the recorded cases of injury, severe or otherwise, the 'live' tube has been placed near the skin.

3. Repeated short exposures produce dermatitis in workers with the rays who are susceptible (cumulative action).

4. Professor Elihu Thomson's artificial dermatitis was produced by a near tube and a long exposure.

5. Negatively, short exposures with the tube at a fair distance are not followed by bad results.

Fortunately, when we come to the discussion of cases, we have a large number recorded by accurate observers. So long ago as February, 1897, Gilchrist* was able to publish a collection of twenty-seven cases. One remarkable instance under his own care was that of a demonstrator, thirty-two years of age, who, after frequent and prolonged focus-tube exposures, developed a severe dermatitis. The bones of the hand became painful upon pressure, and a Röntgen photograph showed distinct osteoplastic periostitis, with a probable osteitis of the first and second phalanges of the index and middle fingers, and also of the heads of the metacarpal bones. Without endeavouring to make an analysis of all recorded cases, mention may be made of a few that raise points of special interest:

In the *British Medical Journal* epitome for August 15, 1896, the case of a young man of seventeen was reported. He was under the care of Marcuse, who found the patient suffering from a diffuse desquamative dermatitis of the face and back. There was also a partially-bald patch on the temple, from which the hairs could be easily extracted.

In the same journal for November 17, 1896, Dr. Drury described a case in which severe results followed two exposures, the first of an hour, the second of an hour and a half. A large surface of the epigastrium became erythematous and swollen; it vesicated on the tenth day, and showed a profuse discharge on the twenty-

* *Johns Hopkins Hospital Bulletin*, No. 71, February, 1897.

fourth day. A troublesome ulcer which ensued was unhealed sixteen weeks later.

In the *Canadian Practitioner* for November, 1896, Dr. King of Toronto reported the case of a young man who for three months was engaged in demonstrating the Röntgen rays, with a daily average exposure of six hours. After about six weeks he had dermatitis of the right arm and hand, which recovered after discontinuing the exposure. On resuming work, however, he had another attack. In about six weeks the hand and face of the exposed side showed signs of a severe dermatitis. The eyelids were œdematous, and there was double conjunctivitis. On the left hand the nails exfoliated and the hairs were destroyed. On the left side the hair was gone from temple, eyebrow, upper lip, side of face, and neck.*

Dr. Radcliffe Crocker, in January, 1897, published the case of a lad who developed a large and obstinate ulceration of the abdomen after a single exposure of an hour's duration. The lower border of the inflammatory area was sharply limited by the clothing, and six weeks later a small, painful ulcer was still left unhealed.

In February, 1897, Professor Waymouth Reid,† a highly-skilled and accurate observer, within four days underwent four exposures, of twenty, forty, fifty, and ninety minutes respectively, and afterwards suffered from a severe dermatitis in the exposed area. The skin lesions were healed by the thirty-third day, but sixty-nine days after the original exposures he reported to the present writer: 'There is no vestige of hair left upon the chest, and I have not been troubled with the shaving of my chin for the last six weeks, the hairs having come out by the bulbs to the touch of the razor twenty-two days after the chest exposure, after a slight preliminary erythema of the skin, not followed by loss of cuticle.' As happens where the focus-tube dermatitis has not caused deep sloughing of the skin, the hair afterwards grew again. Dr. Reid further placed on record the interesting fact that there was an erythema of the back as well as of the chest—that is to say, presumably at the points both of entry and of exit of the irritant rays, unless, indeed, we attribute the result to indirect electrical influences.

* For abstract, see *British Journal of Dermatology*, January, 1897.

† *Scottish Medical and Surgical Journal*, February, 1897.

The last-mentioned point may be compared with a case published by Mr. T. L. Gillanders, M.B. After several exposures, extending over twelve days and including screen examinations and photographs with final screen operation, the patient, while convalescing, developed dermatitis on both sides of the hand. It is not stated, however, that both back and front were not exposed to the focus tube.

Two other instances of double-surface injury are mentioned by Wolfenden* as having come to his knowledge.

Turning next to cases that have come under the author's personal observation, one has already been noted where congestion of a nail-bed followed twenty-fours hours after a four minutes' exposure of a hand, with the tube a foot above the plate.

In July, 1897, the writer reported several instances of deep tissue traumatism. In one striking case the patient suffered from cerebral symptoms suggestive of sunstroke. For a long time he had been in the habit of demonstrating the Röntgen rays, and often had one side of his head within a few inches of a focus tube, with only a wooden screen between. From time to time he suffered from a slight dermatitis, but at length he developed more serious symptoms, of which the chief were headache, vertigo, vomiting, dimness of sight, and great prostration. He placed himself under the care of a medical man at a seaside town, and that gentleman said at the time his symptoms were practically those of sunstroke, a view that he has since kindly confirmed. If we may on such evidence ascribe the cerebral attack to the influence of the focus tube, then its influence upon deep structures must be admitted.

Another case in point came under personal observation. A practical worker with the rays, a healthy middle-aged man, was carrying out a series of experiments that involved exposure of the region of the stomach for a period of about two hours daily. After some weeks he complained of abdominal symptoms, such as pain, tenderness, flatulency, and diarrhœa. He went away into the country for a fortnight, and got well. On his return he resumed his experiments, and after a fortnight experienced a second attack. He then shielded his stomach with a thin sheet of lead, and his symptoms finally disappeared. This history certainly suggests that in his case the rays of the focus tube caused a direct inflammation of the gastro-intestinal mucous membrane. Serious diges-

* *Wright's Medical Annual*, 1899, p. 107.

tive disturbances have also been attributed to *x*-ray exposures by Messrs. Bergoiné and Teissier. They also hint at the possibility of pneumonia having been set up in the same way.

In another group of cases previously unsusceptible persons have been rendered susceptible by altered conditions of exposure. In July, 1897, he described to the Dermatological Society of Great Britain and Ireland an experience of Mr. Webster, a gentleman who has had a wide experience of Röntgen ray work. For a year or more he had undergone constant exposure to the focus tube without bad results. He then injured himself with a metol solution while developing photographic plates, and shortly afterwards a diffuse dermatitis appeared on the back of his hand. The interesting points are the previous damage of skin by the metol and the fact that the dermatitis coincided with the heating of the kathode end of the tube.

In another case kindly communicated by Mr. Webster, an individual had been exposed for something like a score of times within a period of six months. Six weeks after the last exposure the hair fell out from one side of the head. The only differing conditions of experiment, so far as could be ascertained, were that in the last, and presumably the damaging, exposure the kathode end of the Crookes tube had been kept continuously heated.

A striking instance occurred in the person of a gentleman who had made some 2,000 Röntgen exposures, but, having seen no ill-effects therefrom, not unnaturally doubted their occurrence. At the conversazione of the London Röntgen Society, held on November 21, 1898, he exposed his hand to a strange tube, and three days later developed a patch of dermatitis.

The analogy is not a little striking between focus-tube dermatitis and that produced in rare instances by a single exposure to a hot sun, or at any time by sufficiently close or prolonged contact with the heat of a furnace. With regard to all these conditions, we may observe :

1. That the dermatitis may result from a single exposure.
2. That bronzing may occur.
3. That the injury is excluded by clothing.
4. That chemical rays exist in each source of injurious influence.
5. That deep as well as surface tissues may be affected.

1. That dermatitis may follow a single exposure to a hot sun is an established medical fact. In his smaller Clinical Atlas (Plate CX.)

Mr. Jonathan Hutchinson gives an excellent picture of a most severe eruption following that circumstance.

2. Another remarkable resemblance is found in pigmentation. Bronzing, as everyone knows, is a constant result of exposure to the sun; and most folk would connect the black skin of the negro with some inherited peculiarity acquired by ancestral life under a tropical sun. Bearing upon this point is the case where Despeigne used the focus-tube rays to alleviate the pain of cancer, and after the eighteenth sitting found the exposed skin almost as black as that of an African negro. In this connection may be mentioned the bronzing sometimes seen in those exposed to the prolonged influence of powerful electric light.

3. The third point is illustrated by the protection afforded by clothing against sun damage, and in the case of the focus tube by Dr. Crocker's case, where the inflammation was sharply delimited by the clothing. Nor is it possible to recall a case in which either sun or focus-tube dermatitis has occurred in parts protected by clothes. Clearly, this observation alone, if established, would suffice to absolve the *x*-rays pure and simple from any suspicion of traumatic agency, for there is no ordinary clothing which they would not readily penetrate. It is also worthy of note that an assumption of the innocence of the *x*-rays themselves has been applied in the generally used shields of india-rubber, vulcanite, and other materials which offer no resistance to the rays. One may remark, by the way, that the use of such protective appliances involves an obvious fallacy of numbers, inasmuch as persons working under unprotected conditions are so rarely attacked that the vulcanite or other screen would have to be applied in an enormous number of exposures to enable one to arrive at any trustworthy conclusion. If the gentleman already spoken of, who made the 2,000 exposures without bad results, had used a vulcanite shield, he might naturally have ascribed the absence of dermatitis to that precaution, although he would, nevertheless, have thereby strayed into a logical pitfall. A rational method would be to test the results of protected and unprotected exposures on different portions of the body of persons of proved susceptibility. It would be easy to devise a series of experiments under those conditions, planned so as to exclude all the less penetrating rays from the skin surface.

4. That chemical rays are emitted from sun, focus tube, and furnace is a simple physical proposition, capable of ready proof.

5. With regard to the fifth point—namely, that of effect upon deep tissues—that result is recognised in the case of sun-rays, and instances have been adduced to show that a similar action may be exerted by the focus tube. Other facts pointing to deep action of the latter are the relief of pain, noted by Despeigne and others, and the local tremors that not infrequently attend exposure. The analogy between sun and focus-tube action is amplified by a case, seen at hospital in the summer of 1898, of pronounced sun dermatitis, the onset of which was attended by fine tremors, exactly like those set up by the focus tube.

This point of the similarity of the focus-tube lesion to that of severe sunburn is admitted by Gilchrist, who says, however, that the two things are different, because in solar eruptions there is no alopecia and no periostitis. His objection, however, does not appear altogether sound, because there is obviously traumatism to some of the deep structures in sunstroke (whether direct or indirect does not here affect the argument), and it would be impossible, so far as one can see, in our present state of knowledge to demonstrate the selectiveness or otherwise of any particular structure by that deep injurious action. Further, one would be inclined to connect the thickness of the negro skull with prolonged exposure to tropical suns. The following observation, if confirmed, would point to the protective nature of the negro skin. Mr. Albert Walsh, of Port Elizabeth, told the writer that he could not detect a bullet in a black man's thigh, although his apparatus was in good working order, and produced good results in the case of a white man. This observation he has since confirmed, and imagines there may be some special resistance offered to the rays by the negro skin.

In the first edition of this book the view was expressed that, 'on the whole, it seems not improbable that some common agent exists in the rays of the sun, of the focus tube, and of the electric arc light capable of stimulating the human cutaneous surface, and sometimes the deeper tissues of the body, in varying degrees of severity, which are in some way determined by personal predisposing peculiarities.'

A curious confirmation of that hypothesis has been since advanced by Professor Schiff at the Austrian Gesellschaft der Aertzis.* At that society he showed a patient who had been treated with the focus tube rays for lupus. He attributed the

* *Medical Press and Circular*, November 23, 1898, p. 540.

successful result to the chemical action of the rays, and quoted Finsen of Copenhagen, who recorded equal success with rays not produced by Röntgen apparatus. His statement was confirmed by Spiegler, who said he had worked personally with Finsen while carrying out the treatment in question. The sun's rays were usually utilized for the purpose, and were passed through lenses to decompose the light before it was allowed to reach the morbid structures. At a later stage of the experimental treatment an electric arc light was used. 'Little glass plates were laid over an illuminated surface, to produce a sort of anæmia, or the acting ray would have checked the circulating blood altogether.'

It may here be stated generally that the view that the injury is not caused by the *x*-rays, but by some accompanying influence, appears to have gained most favour in France, Germany, and America.

Various theories have been advanced to explain focus-tube dermatitis. Of these the chief attribute the bad results to:

1. Ozone generation in the skin.
2. Flights of minute platinum atoms.
3. Ultra-violet rays.
4. Radiant energy.
5. Rays of *x*-ray order most readily absorbed.
6. Electrical induction.
7. De-electrification.

1. Tesla's view, that the damage is due to ozone generated in the skin, does not account for injury to deep tissues, if we accept that result.

2. There does not appear to be any general acceptance of the theory of the projection of streams of solid particles through the walls of the tube.

3, 4, and 5 may be taken together; the term 'chemical rays' is perhaps wide enough to include them. Dr. Philip M. Jones, of San Francisco, in a paper read before the California State Medical Society, April 20, 1897, attributed the dermatitis to the absorption of radiant energy by the cells of the skin, and thought the process parallel with the changes effected in the photographic emulsion. He agrees with the majority of observers that a bad result is more apt to follow exposure to a tube of low than of high vacuum. The latter fact further tends to exonerate the *x*-rays, for, as

Mr. Gardiner has demonstrated to the Röntgen Society,* 'the greatest production of *x*-rays takes place in tubes of high resistance'—that is to say, the very tubes that, according to most authorities, are the least likely to do harm. Under the same heading of radiant energy comes the contention of Elihu Thomson that 'the burns are produced chiefly by those rays of the *x*-ray order which are most readily absorbable by the flesh.'

6. The theory of electrical conduction appears to be controverted by an experiment of Elihu Thomson's. In a sheet of lead he cut a window, which was divided in two by a strip of tinfoil; one of these he covered with a double layer of aluminium foil, while the other was left bare. This compound shield he placed on a finger, and exposed it to the action of a focus tube. Two burns resulted, one on the part under the aluminium foil and the other on the bare spot. Professor Thomson thinks it inconceivable that any electrostatic effect could have been produced through the aluminium foil more than through the tinfoil or the lead, as all three metals were in electrical contact and subjected to the same conditions.

A further argument against the induction theory may be found in the great amount of harmless electrification of skin often involved in therapeutic or experimental work. At the same time, it seems likely we have yet to learn a good deal about the electrical states that are set up thereby in the skin. In that structure we find externally a thin, hard, horny, non-conducting layer, that lies upon the middle layer of so-called 'prickle' cells, which are bathed in serum, a warm salt fluid. The prickle cells are cut off by the close layer of columnar cells known as the 'palisade' layer from the underlying tissues, charged with warm alkaline blood and serum. All these layers are pierced by the hairs and the sweat-ducts, both hair-bulbs and sweat-glands being in the deeper tissues. When this combination of solid and fluid tissues is injured by exposure to the action of the focus tube, there is a tendency to pick out certain structures, as the hair-bulbs and the palisade layer. In cases of moderate damage, the brunt of the mischief is borne by the palisade layer and by the hair-sheaths. As regards the hairs, one might almost imagine they had acted as conductors of some injurious electrical agency either to or from the body; any way, the reason why hairs alone should be selected by

* *Archives of the Röntgen Ray*, May, 1898, p. 70.

the focus tube is not apparent. The anatomical arrangement of the skin would appear to favour complicated electrostatic conditions. Lastly, it is a noteworthy fact that under certain circumstances the sweat may become acid, a fact which may have a bearing upon the little-understood problems of individual susceptibility.

7. De-electrification, suggested by Dr. Lowe of Lincoln and others, an action known to be brought about by the rays of the focus tube. This hypothesis might explain the peculiar inflammatory selection of the hairs already spoken of.

Dr. A. D. Rockwell* has narrated a case in which an intense dermatitis appeared after the seventh exposure, cumulative action, no doubt, combining with the influence of susceptibility to produce this effect.

In another instance the patient showed a marked idiosyncrasy to ivy poison. Interrogation of the patient as to any special cutaneous susceptibility is, therefore, advisable before commencing treatment.

Röntgen Rays and Sterility.

Tilden Brown and Osgood † state 'that men, by their presence in an *x*-ray atmosphere incidental to radiography, the therapeutic use of or testing of tubes, may, after a period of time, be rendered sterile.' They based this conclusion on the fact that eighteen *x*-ray workers who had consulted them were the subjects either of total azoospermia or of oligo-necrospermia, although none of them had suffered from any venereal disease or local traumatism. None of them presented physical signs of abnormal genital organs, nor were any of them conscious of functional derangement. There was nothing objective or subjective to mark the gradual onset of sterility. It was found on inquiry that all those on whom spermatozoa were absent from the seminal fluid had done extensive *x*-ray work for over three years, while a few who had been so employed for shorter periods showed varying degrees of oligo-necrospermia. Half of the patients were married, but in no single case had one of them had a child since engaging in *x*-ray work. The results of Albers-Schoenberg's experiments on rabbits and guinea-pigs are quoted, and seem to confirm the authors' opinion that the rays

* *New York Medical Record*, January 16, 1904.

† *American Journal of Surgery*, vol. xviii., No. 9, p. 180.

blight the spermatogenetic cells. The authors advise that workers with *x*-rays should protect the genital organs by means of an impermeable shield.

In August, 1906, M. Bouchard read a paper before the Paris Academy of Medicine dealing with the action of the *x*-rays on the ovary of the bitch. He alluded to three observers who in the previous year showed that atrophy of the ovary in rabbits followed exposure to mild doses of the *x*-ray. M. Rouvier repeated those experiments upon both rabbits and bitches, and found that in both the rays exercised a selective action upon the ovaries. There was a variable action, however, for small animals; ovarian atrophy could be induced without destruction of hair. In the bitch, however, a similar result could be obtained only with great difficulty, even when exposures had been carried to the extent of producing dermatitis. From experiments made on the cadaver it was concluded that it would be out of the question to produce atrophy of the ovary in women by the rays, inasmuch as exposure was not recorded on a radiometric pastille placed over the ovary.

VII. THERAPEUTICS.

The curative action of the focus-tube rays has excited much interest. There can be no doubt that under some imperfectly understood conditions they are able to exert considerable influence on the cutaneous surfaces as well as on the deeper tissues of the human body.

It is well known that a cutaneous inflammation can be produced at will by the prolonged exposure of an ordinary focus tube at a short distance from the skin.

There are two affections in which this method of treatment has been specially advocated, namely, hypertrichosis and lupus.

Epilation.

As regards hypertrichosis, or superfluous hair, in mild cases, after a focus-tube exposure the hair falls out with little or no inflammatory reaction, simply to grow again after the lapse of a longer or shorter period. On the other hand, when a severe dermatitis is set up, with sloughing of the parts, the wound may take months to heal, and the resulting cicatrization is so deep as to have com-

pletely destroyed the hair-producing area. The latter event must necessarily be attended with unsightly scarring, as would occur in a burn of an equal degree of severity. The following instance of the mischief that may be caused by attempts to apply this treatment came under the notice of the present writer: A lady, afflicted by an abundant growth of hairs on the lower part of the face, applied to a non-medical operator with the *x*-rays. Her chin was subjected to four exposures of about half an hour each, with the focus tube at a distance of 6 inches from the face. The first two exposures were made on successive days, the third and fourth each after a clear interval of two days. Some ten or twelve days after the commencement of this treatment a severe inflammation of the chin set in, attended by much sloughing and lasting for months. The hairs came off, but the lower part of the face was covered with a deep scar, such as would result from a burn, and became the seat of a chronic irritating and eczematous type of inflammation.

In a case of the above kind it may be well to note that the person who applies the treatment may place himself in a false position. As he is not a medical man, and is applying treatment not generally recognised by the medical profession, he would most likely be mulcted in heavy damages should the patient bring an action against him for personal injury.

It may, perhaps, be added that there is only one scientific method yet available for the removal of superfluous hairs, namely, their destruction by electrolysis. This plan, though tedious, and applicable only when the growth is scattered, has the supreme advantage over chemical depilatories and mechanical epilation that, if properly performed, it is not followed by regrowth.

Drs. Schiff and Freund* remove superfluous hairs with a current that does not exceed 2 ampères and a tension of 11½ volts. The tube is placed at 20 to 25 centimetres from the skin for an exposure of ten minutes, and is applied for thirteen to seventeen sittings. In some of the cases it was noted that the skin showed a brownish discoloration, and black hair turned white before it fell out. Dr. Schiff claims to be able to regulate treatment so that after repeated depilation at length regrowth ceases. The method, however, involves so much risk and uncertainty that it is practically abandoned.

* *Wien. Med. Woch.*, Nos. 22, 24, 1898.

Some people claim success with repeated short exposures—ten minutes. Dermatitis seems to occur now and then, however, in the most skilful hands.

Dr. Neville Wood* applied the focus tube to a woman aged twenty-two, who had considerable overgrowth of hair on the face. Eight months after the cessation of treatment the thick down and hair had not returned upon the chin, but there was a downy growth on the cheeks.

The exposures were of ten minutes' duration applied six times a week, and were attended with one sharp attack of dermatitis. He surmises that ten short exposures are useless; that about twenty will clear the ground for electrolysis, or simple traction, if the ray treatment has to be suspended; whilst between thirty and forty will probably produce permanent destruction of the hairs.

Freund† says that after depilation by the focus tube the hair grows again after two months. By applying the rays, however, three or four times every six weeks, he says that it is possible to keep the face permanently hairless.

In one case, reported by Messrs. Barthelemy and Darien, the hairs grew again, after a period of eighteen months, in a guinea-pig which had been depilated by a prolonged exposure to the focus tube.

Lupus Vulgaris.

In lupus vulgaris we find ourselves faced with somewhat similar considerations. That the malady may sometimes be cured by exposure to a focus tube is undeniable, and the focus tube must be allotted a place in the list of remedies, especially in obstinate and ulcerative cases. At the same time, the fact must be borne in mind that it often disappears under various approved forms of treatment, such as scraping and caustics, and even of internal medication. The present writer has used the focus tube rays in the treatment of lupus of the nasal mucous membrane inaccessible to ordinary methods of treatment.

Dr. Thurstan Holland reported one case of lupus vulgaris of five years' duration, that had been subjected to scraping and other forms of treatment. Eighteen exposures of fifteen minutes each were made, extending over a period of two months. The ulcerated

* *Lancet*, January 7, 1900, p. 231.

† *Wien. Klin. Woch.*, September 28, 1899, p. 966.

lupus patch healed entirely, and three months later was free from recurrence. Dr. Holland has also reported excellent results in the treatment of chronic ulcers by the same plan.

Dr. J. Rudis-Jicisky* reported the cure of a case of lupus erythematosus of the leg by frequent short exposures. The healthy tissues were protected with stanniol, and the tube was placed at a distance of from 15 to 18 inches from the skin. He also found markedly beneficial effects in the treatment of ulcerative lupus vulgaris. This result has been since confirmed by several English observers.

Dr. E. Schiff† of Vienna states that the cases of lupus particularly suitable for radio-therapy are the widely diffused, those complicated by deep ulcerative processes, or those encroaching on the mucous membrane or other situations not amenable to operation.

The mucous membranes of the lips and nose react promptly to the Röntgen rays. These give very favourable results after relatively short treatment, even when the affection of the mucous membrane has gone on to ulceration.

In the lupus cases the reaction always runs the same course, the lupus nodules gradually becoming dark red and turgescent. Moreover, certain dark spots develop in places which previously appeared quite normal, and subsequently take on the character of lupus nodules. Later the nodules drop out, leaving holes which are well defined, as if punched out, and are about the size of a pin's head.

Dr. W. Allan Jamieson‡ has reported favourably upon the rise of *x*-rays in certain cases of lupus vulgaris. The majority of the 133 cases of the disease who persevered in the treatment during the last eighteen months at the Edinburgh Royal Infirmary were materially benefited, if not cured, by the treatment.

Dr. J. F. Schamberg§ considers that, in the hypertrophic, vegetative, and also ulcerative forms of the disease, the *x*-rays are preferable to the Finsen light. It is a curious fact that the scar obtained by *x*-rays in lupus and other conditions is extremely apt to develop telangiectasis. The author treated a small but most

* *American X-Ray Journal*, October, 1896.
† *The Therapeutics of the Röntgen Rays*, 1901, p. 16.
‡ *Scottish Medical and Surgical Journal*, February, 1904, p. 97.
§ *American Medicine*, December 19, 1903.

refractory lupus in front of and involving the lobe of an ear both by *x*-rays and by repeated scrapings. A telangiectasis resulted, and several small recurrent nodules. Both venules and nodules disappeared permanently under the application of radium.

Hodgkin's Disease.

Diminution in the size of the glandular enlargements, met with in pseudo-leukæmia, has been recorded by Dr. W. A. Pusey,* of the University of Illinois (see also p. 384).

Rodent Ulcer, Cancer, and other Troubles.

Stembeck† of Stockholm reports the cure of rodent ulcer on the nose of a woman aged sixty-seven. The sittings took place daily with an exposure of ten to twelve minutes. After the thirty-fifth application improvement took place, and ultimately the ulcer healed, its position being shown by a smooth covering differing only slightly from the neighbouring skin.

Rodent ulcer has also been successfully treated by focus-tube exposure. Dr. J. H. Sequeira‡ reported twelve cases, in three of which the ulcer healed, eight were in course of healing, and one gave up treatment, so that in no instance was there a disappointing result. He was led to try the Röntgen method upon a patient who suffered from a severe rodent ulcer, but who could not bear the pressure of the special apparatus used in the Finsen light treatment. As the result of his experiments, he feels justified in recommending the use of the *x*-rays—at least, in cases where complete removal by the knife is impracticable.

Mr. Andrew Clark§ has published a case in which a large ulcerating carcinomatous surface involving the whole of the right breast cicatrized under several months' use of the focus tube. The woman was sixty years of age, a sister had died of cancer, she had some syphilitic ulcers on legs, and was treated with iodides while undergoing the *x*-ray treatment. Some enlarged glands in the axilla decreased in size.

The cure of epithelioma by focus-tube exposure has been reported

* *Journal of the American Medical Association*, January 18, 1902, p. 168.

† *Hygeia*, Stockholm, 1900, p. 18. *Mittheilungen aus d. Grenzgebiete d. Med. und Chir.*, Bd. vi., No. 3.

‡ *British Medical Journal*, February 9, 1901, p. 332.

§ *Ibid.*, June 8, 1901.

from various quarters. Dr. F. H. Williams, of Boston, has treated eleven cases of flat epithelioma of the face with excellent results.

Mr. L. H. Harris, M.B.,* of Sydney, has recorded an interesting case of removal of hypertrophied scar-tissue by the Röntgen method.

The patient was a young woman who showed a somewhat extensive scar fifteen months after the removal of some tuberculous glands. After thirty-two sittings the hypertrophied scar, which had been ½ inch thick in some places, disappeared, leaving only the mark of the original skin incision.

The cure of a port-wine stain has been reported by Jutassy. The whole of the right side of the face was affected, and treatment involved a severe dermatitis, which took two months to heal, leaving a smooth white scar.

Drs. T. Sjögren and G. Sederholm,† of Stockholm, have published a series of cases of various kinds treated with the focus tube. They are inclined to attribute the therapeutic action to the invisible *x*-rays, while the ultra-violet rays mixed with them have little to do with the beneficial effects. The authors were disappointed with results in twenty-seven cases of lupus vulgaris on account of the resistance of the lupus nodules. Recurrences were about equal to those met with in patients treated by other methods. Lupus erythematosus required considerable reaction, but was successful in the long-run, and the same remark applied to tuberculides or scrofuloderma. Results were excellent in chronic eczema, pruritus, in two chronic ulcers (cure), in acne with hypertrichosis, in epithelioma and rodent ulcer, and in warts. They appear to be doubtful as to the value and application of the method for depilation in cases of hypertrichosis, owing to the difficulty of controlling the degree of reaction. Two cases of psoriasis received no benefit under the focus-tube exposure.

The pathological changes in the skin have been investigated by Gassmann and Schenkel, and by Unna.‡ As might be expected, there is nothing specific in the inflammatory changes set up in this form of dermatitis. Unna concluded that the more resisting histological elements of the skin were involved in the process.

* *Australasian Medical Gazette*, April 20, 1901.

† *Fortschritte auf dem Gebiete der Rontgenstrahlen*, Band iv., Heft 1, June, 1901.

‡ *Fortschritte*, vol. ii., p. 128.

The time taken up in the treatment of patients can be materially shortened by running two or three tubes from the same coil and making several exposures simultaneously. The possibility of doing this has been demonstrated by Mr. H. W. Cox, who found that with a powerful coil and a Mackenzie Davidson break he had no difficulty in lighting up three focus tubes arranged in series.

Cancer: Pathology.

At a meeting of the Pathological Society in December, 1902, Mr. Mayon gave a demonstration of the histological changes produced in rodent ulcer by *x*-ray treatment, changes which apparently led to a cure. A distinct process of inflammation was set up; leucocytic infiltration occurred to a marked degree around the clumps of epithelium, the cells of which became vacuolated and ultimately necrosed. The inflammation, which it was noted was greatly increased by simultaneously dressing the ulcer with irritants such as a 1 to 20 carbolic lotion, did not reach its height until one to three weeks after the commencement of the treatment.

Recent researches confirm the value of *x*-rays in rodent ulcer and in cutaneous epitheliomata. Rodent ulcer can be definitely cured by this means, especially if combined with radium. In cases where the floor of the ulcer is thickened and warty, matters may be hastened by a surgical 'scraping.' As regards surface epitheliomata, encouraging results are reported by C. M. Williams,* who found that out of eighteen cases treated with the rays, there was no recurrence in ten of them after a lapse of from four to twenty-one months.

Results of *x*-ray treatment in deep-seated malignant disease also afford encouragement. Thus, in twenty-six such cases affecting the breast, Leonard † reported apparent cure in no less than nine; while Schiff ‡ has recorded the cure of advanced and undoubted mammary schirrus.

Inoperable Cancer.

Dr. William B. Colly,§ of New York, believes that we have in the *x*-rays a powerful weapon against the growth of malignant

* *American Journal of Medical Sciences*, March, 1905.
† *American Medical Journal*, October 15, 1904.
‡ *Johns Hopkins Hospital Bulletin*, June, 1904.
§ *Medical Record*, March 21, 1903, p. 451.

tumours, and records seventy-five cases of inoperable sarcoma and carcinoma of many different organs, in all of which marked relief was afforded by exposure to the rays.

Cancer of Special Regions.

The Larynx.

Dr. Leonard C. Dobson* has related a case of laryngeal carcinoma in a man, aged sixty-four, in whom tracheotomy had been performed and cachexia was pronounced. The growth was exposed to the influence of the *x*-rays, and an almost immediate improvement was observed, the patient gaining weight and strength. The growth had also shrunk considerably in size. He ultimately died, but not until one year and ten months after the operation of tracheotomy.

The Skull.

Ali Krognis† has reported a case of multiple sarcoma of the bones of the skull in a patient, aged forty, who had had repeated operations, but recurrence had always taken place. The growth was of the small-celled variety, arising from the periosteum. Some of the tumours were exposed to the action of the *x*-rays, and were observed to undergo a remarkable diminution under the treatment.

Dr. Reginald Morton,‡ medical officer in charge of the electrical department at the London Hospital, has observed a case of recurrent sarcoma of the scalp to disappear entirely after *x*-ray treatment, with no sign of recurrence after seven months.

The Uterus.

Professor Sinclair Tousey,§ of New York, has found in several instances that malignant disease of the uterus has been arrested by exposure to *x*-rays.

He employs a tube of 40 centimetres' capacity, of medium hardness, and the exposures of five to six minutes are made at a distance of about 9 inches from the abdomen.

The special points observable in the course of the treatment were the marked relief from pain, the cessation of the vaginal discharge, and in some cases the disappearance of a tumour.

* *West London Medical Journal*, January, 1904, p. 46.
† *Finska läk. Handlingar*, August, 1903, p. 65.
‡ *British Medical Journal*, April 23, 1904, p. 942.
§ *Medical News*, November 14, 1903, p. 921.

Inoperable Uterine Myomata.

Deutsch * of Munich has reported the case of a woman, aged forty, who was affected with an enormous fibromyoma, and who declined operation. Altogether 120 applications of the *x*-rays were made, and in two years the size of the tumour had greatly diminished and the uterus had become much more movable.

Epithelioma.

Dr. F. S. Burns,† of Boston, considers that epithelioma of the skin yields the most constant and encouraging results with *x*-ray treatment.

Dr. W. N. Sweet, ‡ of Philadelphia, has reported a successful result in eighteen out of twenty cases of epithelioma of the eyelids after treatment by means of the *x*-rays.

At the International Congress of Dermatology, held at Berlin in September, 1904, Lassar was firmly convinced that *x*-rays are the means of treatment for rodent ulcer, and Buschke and Schmidt were of the same opinion.

Professor J. Clark Stewart,§ of Minnesota, concludes, as a result of his investigations upon a case of epithelioma of the hand, that the main histological changes produced by the *x*-rays in this disease are (1) fatty degeneration of epithelial cells; (2) the formation of new bloodvessels, especially around the epithelial pearls; (3) marked leucocytic infiltration; and (4) hyaline degeneration and necrotic changes in the epitheliomatous tissue, in the course of which bodies indistinguishable from those described by Plimmer are found.

Mycosis Fungoides.

Dr. Allan Jamieson|| has recorded a case of this disease in a married woman, aged fifty-four, in whom the nodules melted away and the irritation subsided under the influence of the rays.

Good results have also been obtained by Brocq, Scholz, and Brooke.

* *La Semaine Médicale*, September 21, 1904, p. 304.
† *Boston Medical and Surgical Journal*, October 29, 1903, p. 481.
‡ *Proceedings of the Philadelphia County Medical Society*, November 30, 1903.
§ *Journal of the American Medical Association*, July 18, 1903.
|| *British Journal of Dermatology*, January, 1903, p. 1.

Psoriasis.*

Drs. Hyde, Montgomery, and Ormsby, have reported favourably upon the influence of the *x*-rays in psoriasis. The scales become more easily detached, and the itching which is sometimes present is relieved. Recurring patches are generally removed with fewer exposures than were necessary for the original ones.

Eczema.

In the more chronic varieties of this disease Hahn and Schiff have had some good results after exposure to the rays.

Lassar and Schmidt† find that the *x*-rays are of great service in eczema, particularly when the disease threatens to become chronic. Several cases of pruritus associated with eczematous eruptions are recorded in which radiography has been employed with considerable benefit.

Acne Rosacea.

This is also favourably influenced by the *x*-rays.

Acne Vulgaris.

Drs. L. Török and M. Schein‡ believe that exposure to the *x*-rays is the most effective form of treatment yet known. Under its influence the abnormal secretion of sebum is checked and the lanugo hairs fall.

Pruritus.

M. Leredde has stated that the anti-pruritic effect of the *x*-rays is of great therapeutic value, as they undoubtedly possess an analgesic action which is capable of relieving this distressing symptom.

Internal Fluorescence and the X-Rays.

Dr. W. J. Morton,§ of New York, has propounded the theory that artificial fluorescence of the living tissues may be instrumental in modifying or even in curing certain forms of malignant disease. The procedure consists of two parts, the administration of a fluorescent fluid and the use of the *x*-rays, or some similar agent,

* *Journal of the American Medical Association*, January 3, 1903, p. 4.
† *Dermatol. Zeitschrift*, Berlin, XI., No. 1, p. 11, and No. 2, p. 95.
‡ *Wien. Klin. Rundschau*, No. 37.
§ *New York Medical Journal*, February 13, 1904, p. 300.

by which fluorescence is excited within the body. Dr. Morton has reported cases of Hodgkin's disease, rodent ulcer, and cancer which have been cured by giving a fluorescent substance like quinine or æsculin internally, and then exposing the patient to the influence of the rays. Much of his work in the therapeutics of the focus tube is marked by extreme thoroughness and originality. If his results with the combined fluorescence and focus-tube action be confirmed, he will have opened up a fresh and attractive field of medical investigation.

Dr. S. Tousey* believes that radio-active or internally fluorescent solutions may also be of service in the diagnosis of such gastric affections as simple dilatation, for if the gastric contents be mixed up with some radio-active substance, administered internally, the outline of the stomach can be much more readily seen with the fluoroscope and also in a radiograph.

Pruritus Ani.

Dr. J. Rawson Pennington,† of Chicago, has reported thirteen cases of pruritus ani, all of which yielded to *x*-rays. Many of these were of long standing, complicated by the presence of eczema or scar-tissue, and had resisted all previous treatment.

Chronic Ulcer of Leg.

W. L. Heeve‡ has described twenty-four cases of chronic ulceration of the leg treated by exposure to the *x*-rays with a considerable amount of success. The ulcer was first carefully cleansed with green soap, and exposures of ten to fifteen minutes were given every third day.

Nævus.

Dr. J. R. Levack, of Aberdeen,§ has reported three cases of cutaneous nævi treated by *x*-rays in which daily exposures of ten minutes were given. In one case, a *nævus flammeus*, the affected area became swollen, red, and the cuticle gradually peeled off, leaving a raw, discharging surface. Three months later this had quite healed, and the skin was quite soft and apparently healthy.

* *Boston Medical and Surgical Journal*, April 21, 1904, p.

† *New York Medical Journal*, February 20, 1904, p. 356.

‡ *American X-Ray Journal*, September, 1903.

§ *Scottish Medical and Surgical Journal*, July, 1904.

Dr. Levack concludes that the treatment is, on the whole, satisfactory, though somewhat tedious.

Xanthoma Multiplex.

Dr. Henry Whitehouse, of New York, has described a case at the annual meeting of the American Dermatological Association, in June, 1904, of a woman, aged thirty-four, who presented numerous lesions of xanthoma planum. There was no visceral disease and no jaundice. Marked improvement resulted from the use of *x*-rays.

Radio-Therapy in Skin Diseases.

Dr. William Pusey,* of Chicago, read a valuable paper on this subject at the last meeting of the American Dermatological Association, at Washington, in which it is stated that the microscopic appearances in the tissues after treatment by *x*-rays are very uniform, and consist chiefly in hyperplasia of the prickle-cell layer, increased formation of pigment and kerato-hyalin, breaking up of the nuclei of the cells, and a development of new bloodvessels. He concludes that the following properties of the *x*-rays render them especially suitable for therapeutic application:

1. Their action in causing atrophy of the appendages of the skin.
2. Their destructive action upon organisms in living tissues.
3. Their effect upon the metabolism of tissues.
4. The power of destroying certain pathological tissues.
5. Their anodyne action, especially in neuralgias, malignant growths, and in diseases of the skin accompanied by itching.

In reviewing the later researches into the pathological action of the Röntgen rays upon the skin, MacLeod (*British Journal of Dermatology*, October, 1903, p. 372) finds, in addition to the above, that in small doses they have a distinctly stimulating effect upon the elements of the healthy skin. Larger doses produce devitalization of the tissue-elements, while their cumulative effects are responsible, to a large extent, for the inflammatory reaction which sometimes results from their use.

Focus-tube Dermatitis.

At the Newcastle-upon-Tyne Clinical Society a case was shown by Dr. A. H. Hobbs.† A woman had been subjected to the rays

* *Journal of Cutaneous Diseases*, August, 1903.

† *Lancet*, February 17, 1900, p. 466.

six months previously for loose body in the joint. Sixteen days later the skin which had been most exposed to the rays developed an inflammatory condition, and in three to four weeks a well-marked bulla appeared. An ulcer, which was intractable to treatment, resulted, and was present when the patient was shown to the society. The slowness of development of the injury is remarkable.

Favus.

Norman Walker* has reported favus successfully treated.

Alopecia Areata.

Herr M. R. Kienböck showed a man, twenty-six years of age, suffering from alopecia areata of several years' duration. The Röntgen rays were applied to one particular area, and after six applications of a quarter of an hour each a growth of hair was observed.

The effects of the rays in alopecia areata are somewhat variable, some observers, as Heidingsfeld, having abandoned their use in favour of chemical stimulating applications. Holzknecht has reported a successful cure in four months of extensive alopecia in a youth of eighteen after *x*-ray treatment.

It is evident, then, that we have in the focus-tube rays an agent capable of acting powerfully upon the skin and its appendages. At the same time, while similar effects can be obtained by simpler and safer means, their action is still so uncertain, so difficult to regulate, and so apt to be attended with serious complications, that, beyond the treatment of ringworm, it is not likely to have any but limited application to the therapeutics of the cutaneous surface.

Tinea Tonsurans.

Sabouraud† has succeeded in considerably reducing the period of treatment of ringworm of the scalp. The tube is protected by a metallic casing, except at the bulb, where an aperture is fitted to a metallic cylinder with adjustable diaphragm. This is placed over the area to be treated, the exposure averages twenty minutes, distance 15 centimetres; a dose is measured by coloration of

* *Lancet*, June 6, 1900.

† *Annales de l'Institut Pasteur*, January 25, 1904, p. 7.

pastilles placed on scalp. The *x*-rays do not act as a parasiticide; they cause an expulsion of the diseased hairs, which become separated from their papilla by a gradual narrowing of their roots. New hairs are formed beneath these. During treatment daily washing with an antiseptic soap is practised, this being most essential in order to prevent infection of other parts of the scalp. At St. Louis the duration of the treatment averages about three months, as against eighteen by previous methods.

Dr. J. Bullen's plan is to paint a boy's ordinary cap with white lead, covered in with muslin. Holes are then cut in this screen corresponding to the patches of ring-worm, which are then exposed to the *x*-ray tube.

Sclerodermia.

Stainer* reports a case of linear sclerodermia in a girl, aged sixteen, in which improvement had resulted from the application of *x*-rays.

Morphœa.

Dr. G. E. Pfahler† reports the case of a lady, aged twenty-five, who was cured of a patch of morphœa (localized sclerodermia) by exposure to *x* rays.

The author has treated a similar case, with results that showed the focus tube exercised a marked influence upon the affected area. There was nothing to suggest, however, that a cure might be reasonably expected by prolonged application.

Sycosis.

Opinions differ somewhat as to the effect of the rays upon this disease, but Abraham and Meachen have seen distinct improvement resulting from their use. The diseased hairs become loosened, and pulsation soon disappears. The author has treated several such cases, in some of which marked improvement has ensued, especially as regards the rapid disappearance of nodular swellings.

Folliculitis of the Beard is stated by Dr. F. S. Burns, of Boston, to yield to the influence of the *x*-rays.

* *Transactions of the Dermatological Society of Great Britain and Ireland*, vol. ix., p. 48.

† *Journal of the American Medical Association*, August 6, 1904, p. 375.

Deep Therapeutic Action.

Turning next to the possible therapeutics of the focus-tube rays upon the deeper structures, we find ourselves confronted with a variety of interesting and suggestive facts.

In some instances exposure to the rays has been followed by a cessation of pain, but the casual relationship between the two conditions can hardly be regarded yet as scientifically demonstrated. Probably the first notice of the kind was by Dr. Richardson* of Boston, who wrote to a medical journal on August 31, 1896, describing the results of an examination by the rays. The patient was a stout woman of fifty, who had been complaining of pain on and off in an old fracture near the ankle-joint. She had an exposure of five minutes, and three weeks later wrote stating that, in the interval, not only had she been free from pain, but that swelling and soreness had also disappeared.

M. V. Despeigne,† of Lyons, reported a case under the care of L. Voight. The patient suffered from a small epithelial cancroid nodule of the mouth. The rays were applied twice daily for periods of half, and sometimes a quarter, of an hour. The pain, which had been considerable, almost immediately ceased, so that the medical attendant was enabled to discontinue the morphine. The patient died eventually of pneumonia, but a prolonged palliative effect had followed the effect of the rays.

In a previous case in his own practice, M. Despeigne found that a cancer actually decreased in volume under the influence of the focus tube. His conclusion from both cases is that, when applied to cancer, the rays have a distinct anæsthetic effect, and cause a general improvement in the condition of the patient, but exert little influence upon the growth. (As a matter of fact, surgeons are thus provided with a new anæsthetic for the relief of malignant growths far less disastrous in its general results than the evils incident to morphinism.)

Stembo claims to have cured a number of cases of neuralgia.‡ He admits that the rays act partly by suggestion, but states that when the anodal rays are substituted for the kathodal, without the patient's knowledge, no analgesic effect is obtained. Relief was

* *Boston Medical and Surgical Journal*, September 3, 1896.

† *Lyons Medical Journal*, December 28, 1896.

‡ *Therapie d. Gegenwart*, June, 1900, p. 250.

usually obtained in three applications, but if ten applications brought no relief the treatment was abandoned.

Stembo has used the rays for the relief of pain in thirty-seven cases. In twenty-eight it was carried out thoroughly, and twenty-one were cured of various neuralgias, such as trifacial, occipital, cervico-brachial, intercostal, visceral, and sciatic. He was led to employ the rays as an analgesic because patients who had been examined for diagnostic purposes remarked they had been relieved of pain. He used an apparatus with a spark of from 12 to 18 inches, and about 1,500 interruptions per minute. The distance of the antikathode from the part varied from 8 to 20 inches. The unaffected part was protected by tinfoil. Sittings were made every other day, and lasted from three to ten minutes. Stembo thinks it essential that, on gently touching with the tips of the fingers the part of the body to which the rays are being directed, a slight pricking sensation should be felt.

Sokonow of St. Petersburg has applied the focus tube in four cases of articular rheumatism in children, and states that he has obtained good results.

Some observers have also met with success in the treatment of elephantiasis.

There have been many rumours as to the action of the Röntgen rays upon blind eyes. The scanty nature of the evidence as to the action of the rays upon the optic nerve-endings may be gathered from the following reports :

The case of a blind man was reported to the North-Western Electrical Association by Mr. Hoskin. The patient was unable to see the light of an arc lamp close to his face. His eyes appeared normal, but he had been completely blind for two years. On being placed before a Röntgen apparatus in action, he was able to describe the general outline of the tube. A sheet of cardboard interposed cut off all visual impressions.

In this case, accepting the above statements, as Röntgen rays penetrate cardboard, any visual stimulation must have been due to some other kind of ray. If the media were transparent, and the optic nerve insensitive both to day and to ordinary electric light, then it follows, if the focus-tube rays stimulated the nerve, that there must be special nerve endings excited by the rays, although not by ordinary light, supposing the action to be local. Of course it is not impossible that the rays might have penetrated the brain

and stimulated the perceptive centres. In that case, however, we should expect to have had a similar phenomenon recorded by non-blind persons; besides, there is no reason why the figure of the tube should be fixed on the perceptive centre. In short, the case does not bear analysis.

The retina, it should be borne in mind, is a transforming apparatus which stands between outside rays of light and the percipient nerve and nerve centres. There is, again, a purely psychic blindness of hysterical nature, and any strong impression might cause a person affected in that way, not only to see for a time, but to be permanently cured. Clearly, were an experience of that kind to be encountered by an experimenter unversed in medical matters, he might well imagine he had found a talisman for sightless orbs, and telegraph to that effect across the Atlantic.

Locomotor Ataxia.

Dr. J. Monroe Liebermann,* as the result of the application of the *x*-rays in ninety-six patients suffering from locomotor ataxy, concludes that relief may be afforded in a certain number of early cures as regards pain, inco-ordination, and ocular symptoms.

Ulcerative Colitis.

Mr. Shenton† has published an interesting case where the *x*-rays applied for a month failed to give relief in a case of ulcerative colitis. The patient, however, was completely cured by a prolonged application of high-frequency current. The same observer mentions three other cases of colitis cured in the same way, one after a course of three months and the other two in six weeks

(The author has also had good results with high-frequency current in colitis, and rapid cure in some severe cases of hæmorrhoids.)

Epilepsy.

The treatment of epilepsy by *x*-ray application was first advocated by Branth in America. He considered that the seizure was probably due to instability or abnormal metabolism of the cells of the cortex, which might be stimulated into greater vital activity by the *x*-rays. He claimed that in some cases the number of seizures was very greatly reduced. Dr. Manders‡ has reported a case benefited by the rays.

* *New York Medical Journal*, February 18, 1905.

† *Archives of the Röntgen Ray*, No. 61.

‡ *Ibid.*, No. 57.

Dr. J. Herman Branth* believes that the *x*-rays are not without considerable influence upon cases of epilepsy, providing that cerebral degenerative changes are not far advanced. He has reported the case of a lad of fourteen in whom bromides were of very little use, the fits becoming more and more frequent. The bromide was withdrawn, and *x*-ray treatment applied to the head. The interval between the fits became longer, and the prostration following a convulsion was less severe than formerly.

Hodgkin's Disease.

Dr. S. B. Childs,† of Denver, has reported a case of lymphadenoma in a man, aged thirty-three, which improved greatly under applications of the rays. The spleen and all the enlarged glands decreased in size.

A similar result was obtained by Dr. Edward B. Finch,‡ of New York, in a youth of eighteen. In this case there was an increase in the polymorphonuclear (neutrophile) leucocytes observed after the forty-fourth exposure to the rays.

Leukæmia.

Dr. Nicholas Senn,§ of Chicago, has recorded a case of splenomedullary leukæmia in a Jewess aged twenty-nine. The spleen was enormously enlarged, reaching nearly down to the pubes. Medicinal treatment had been without effect. The spleen, sternum, and epiphyseal extremities of the long bones were exposed to the *x*-rays for about ten minutes daily. After six weeks the spleen had diminished greatly in size, and the myelocytes and eosinophile cells had gradually disappeared.

MM. Guilloz and Spillman,‖ of Nancy, showed before the Société de Biologie a girl, aged seventeen, who had been treated by the *x*-rays for five minutes daily for two years. Great diminution in the number of leucocytes and in the volume of the spleen was observed, and the epistaxis, which had been a troublesome feature, ceased.

The action of the *x*-rays in this affection has been studied in

* *Medical News*, February 27. 1904, p. 425.
† *Ibid.*, January 24, 1903, p. 148.
‡ *New York Medical Record*, May 14, 1904, p. 773.
§ *Ibid.*, August 22, 1903.
‖ *La Semaine Médicale*, June 1, 1904, p. 174.

America by Drs. Joseph A. Capps and Joseph A. Smith,* who have found that chronic cases are more benefited by this treatment than acute. It is believed that the rays exert a local influence, which produces a mild inflammatory reaction in the spleen and lymphatic glands, and also that toxins are formed which possess an inhibitory effect upon the leucocygenic function of the bone-marrow.

That the reduction in the number of leucocytes may be rapidly produced is seen in the case of a man, aged thirty-eight, exhibited by Dr. David McAskie,† of Tottenham, before the North-East London Clinical Society. This patient had an enormous spleen and a leucocyte count of 392,000. After three weeks of the application of the rays twice a week this figure was reduced to 40,000, and the volume of the spleen had diminished by 2 inches.

Dr. Morton, of New York, has also done some excellent work.

Granulation Tissue.

Professor E. Schiff,‡ of Vienna, has reported a unique case of inoperable cancer *en cuirasse* affecting the left mamma. There was considerable ulceration of the surface. Great improvement had taken place after exposure to the *x*-rays.

A fragment of the ulcerated surface in course of reconstitution in the immediate vicinity to the ulcerated surface was taken and examined histologically. This showed newly-formed capillary arches, ranged in typical order.

Leucocythæmia.

Marked improvement follows exposure to the rays in leucocythæmia. The enlarged spleen rapidly diminishes in size, and the number of leucocytes in the blood may fall from 500,000 per cubic millimetre to the normal. The large, finely granular myelocytes, so characteristic of this malady, gradually decrease in number, and may disappear altogether.

Dr. R. J. M. Buchanan§ thinks that the action of the rays in

* *Journal of the American Medical Association*, September 24, 1904, p. 891.
† *Medical Press and Circular*, December 7, 1904.
‡ *Johns Hopkins Hospital Bulletin*, June, 1904.
§ *British Medical Journal*, July 14, 1906, p. 75.

leukæmia is of a twofold character—(1) by inhibiting overproduction in the marrow, and (2) by a destructive influence over the leucocytes themselves. He points out that the myelocytosis recurs rapidly when the *x*-ray treatment is discontinued.

Mr. J. C. L. Ledingham has published a valuable paper on a case in which the white cells fell in six weeks from 200,000 to 20,000 per cubic millimetre, with an appreciable rise of red blood cells at the same time (noted also by Arneth., *Münch. Med. Wochens.*, 1905, pp. 33-34). Suspension of radio-therapy for three months raised the number of white cells to one-third of their number at the commencement of treatment. Ledingham says this certainly shows that the radio-therapy exercised an inhibitory influence on the proliferative function of the blood-forming organs. On a second course the white cells fell in six weeks to the subnormal level of 7,000. Soon afterwards he developed bronchitis; the white cells ran up to 43,000, and he died in a fortnight. This observation is not in accordance with the well-established fact that the intercurrent affection of leukæmia produces a great fall of leucocytes.

Mr. Ledingham remarks:

'The opportunity was thus afforded me of comparing the organic lesions with those described by Heineke,* Mosse and Milchner,† Halber and Linser,‡ and others in experiments on animals. Heineke found that the exposure of small animals, such as mice, to the *x*-rays produced a destruction of the lymphoid follicles in the spleen and lymph glands. The nuclear detritus was taken up by phagocytes, and the node was replaced by connective tissue and epithelioid cells. Prolonged exposure was followed by partial destruction of the granular cells of the marrow. Mosse and Milchner showed that in animals exposed to the *x*-rays the bone-marrow is profoundly influenced. The changes affect principally the cells of the neutrophile series, which are greatly diminished in numbers, the surviving cells exhibiting great deficiency of granules. The experiments of Halber and Linser are even more remarkable. By prolonged exposure of small animals to the *x*-rays they were able to deplete the circulating blood entirely of leucocytes (as measured by ordinary counting methods). The larger the animal the more difficult it was to free the blood of leucocytes, and frequently in rabbits and dogs it was impossible to get lower counts than 1,500 or 2,000 by continued exposure. They maintained from examination of films that the destruction of leucocytes took place in the general circulation, and not in the blood-forming organs. Further, fatal results sometimes ensued, which they attributed to the evil effects of leucotoxins set free from the broken-down leucocytes. The serum

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* Heineke, *Mittheilungen aus d. Grenzgebiete der Medicin und Chirurgie*, Heft 5, 1905.

† Mosse and Milchner, *Berlin. Klin. Wochens.*, No. 49, 1904.

‡ *Loc. cit.*

of *x*-rayed animals had also the power of causing the destruction of leucocytes when injected into fresh animals.'

Mr. Ledingham thinks the greatest caution should be exercised in continuing *x*-ray treatment when the white cells have reached normal limits.

'No satisfactory explanation,' he says, 'has yet been given of the enormous improvement which almost invariably occurs in the general condition of the patient under the *x*-rays. It is at least difficult to bring it into relationship with the blood changes. Of course, on the assumption of Senn and Ahrens that the *x*-rays inhibit the development of, or actually destroy, the hypothetical parasite of leukæmia (Löwit), this improvement in the general condition would find ready explanation.'

Hydatid Cysts.

A. Diaz de la Quintana * narrates the case of a patient with an enormously enlarged liver, in the left lobe of which fluctuating spherical masses could be felt. Hydatid fremitus was present. Forty-seven applications of the *x*-rays, each of ten minutes' duration, were made weekly. Marked improvement occurred, the first symptoms to disappear being those connected with the digestive tract. Finally the tumours disappeared.

Constipation.

M. Albert Weil read a paper before the Medical Congress at Grenoble, held in August, 1904, upon the application of *x*-rays to the abdomen in cases of obstinate constipation. He found that by this means a regular action of the bowels was obtained when all other treatment had failed.

Effects of X-Rays in Colour-blindness.

It has been stated in various quarters that the *x*-rays had a peculiar effect on the retina of colour-blind persons. In order to test the assertion, Mr. Sydney Stephenson and the writer made an investigation upon four colour-blind children. They concluded that there was no reason to suppose that the retinæ of these colour-blind children reacted to the Röntgen rays in any way differently from those of ordinary people with full colour-sense.

* *El Siglo Medico*, August 7, 1904, p. 529.

It has been said that about 1 person in every 800 is blind to the Röntgen rays; that is to say, he is unable to distinguish the shadow pictures on the fluorescent screen. This want of perception has been called Röntgen-ray blindness. That term, however, is clearly a misnomer, as it is not the rays that the observer fails to see, but their effects. In all cases the faculty of distinguishing detail in screen shadows requires to be carefully cultivated. If an individual fail to see well-marked objects on the screen, it may be due to colour-blindness to the yellow shade of the ordinary screen. In that event it would be interesting to try if he were blind to a screen having a different tint of fluorescence. In estimating the degree of screen perception, the acuteness of the individual vision and visual errors (myopia, astigmatism, presbyopia, etc.) should be considered.

Effects in Tuberculosis.

Messrs. Lortet and Genoud* have experimented on guinea-pigs, with a view to ascertaining whether the tube rays had any restraining effect upon acute tuberculosis. Eight of those animals were inoculated with tubercle culture, and three submitted daily to the action of the *x*-rays. At the end of six weeks the latter presented considerable differences from the others that had not been so treated. Those that had undergone the exposures had no abscess at the point of inoculation, the glands were well defined, and their generally good condition was proved by an increase of weight. On the other hand, the inoculated guinea-pigs that had not been under the rays showed abscess at the point of inoculation, enlarged glands, and bad general condition, with loss of weight.

Mr. Brunton Blaikie,† of Edinburgh, found that the Röntgen rays had no visible action upon the growth of cultures of tubercle bacillus. He also found that guinea-pigs inoculated with diphtheria toxine, and exposed to the rays, lived actually a shorter time than those not exposed.

Dr. J. B. Ransom,‡ of New York, has reported forty cases of different tuberculous lesions of bones, tuberculous ulcers, and even some of chronic pulmonary phthisis, of which eight were cured and thirty improved by exposure to the *x*-rays.

* *La Revue Scientifique*, J. L. Breton, p. 106, Paris, 1897.
† *Lancet*, July 25, 1896.
‡ *New York Medical Record*, February 27, 1904, p. 331.

Tuberculous Peritonitis.

Dr. A. Dean Bevan,* of Chicago, has seen disappearance of the masses in the abdomen in tuberculous peritonitis after exposure to the *x*-rays.

* *Journal of the American Medical Association*, January 2, 1904, p. 26.

E. OBSTETRICS AND GYNÆCOLOGY

OBSTETRICS

At first it was hoped that the Röntgen rays would prove of great service in obstetric medicine. In practice, however, up to the present time, experimenters have found its application to the pregnant uterus surrounded with many difficulties. The chief obstacles are: (1) The thickness of the parts to be penetrated; (2) movements, abdominal, uterine, and fœtal; (3) the difficulty of keeping a pregnant woman for any length of time in a constrained position; (4) the distance of the uterus and its contents from the sensitive plate.

The advantages of a good pelvic record of the kind are so obvious that they need hardly be mentioned at length. It would be possible, for instance, to ascertain the presence of twins, superfœtation, lithopædia, monstrosities, fœtal deformities, and malpresentations; while in any case pelvic deformities and exostoses could be demonstrated with ease and certainty. The demonstration of moles and of extra-uterine fœtations offers another attractive field of research.

There is one direction in which Röntgen diagnosis may prove of the utmost value to the obstetrician—namely, in the exact estimation of pelvic diameters and deformities. By means of localization precise measurements of all the bony outlets can be obtained, and the desirability of inducing premature labour or the necessity of removing a full-term fœtus by operation thereby indicated. This fact reduces pelvimetry to an exact and easily-applied art. In France much attention has been bestowed upon this practical point by Professors Budin and Pinard. A stereoscopic view of a pelvis furnishes the observer with a perfect apprehension of the relation of all bony structures.

When taken from the uterus, an *x*-ray photograph can be readily obtained of the fœtus, such as that shown in 1896 by Dr. Oliver. His patient, a woman of thirty-nine, was diagnosed as having an extra-uterine fœtation some two months beyond full term. An unsuccessful attempt was made to secure a record of the tumour in the living body. Upon operation an ovarian sac was removed containing a nine-months fœtus, of which the accompanying excellent picture was obtained (Fig. 168). The interesting observation was made that the ovarian sac was very opaque to the rays. Since then many similar photographs have been published of the human fœtus in various stages of development.

A further important contribution to the study of fœtal radiography was made by Professor Davis,* of Jefferson College. He published a radiogram which showed a faint tracing of the fœtal skull, contrasting strongly from the dark pelvis in which it had been placed. He further pointed out that the fœtal skull generally, except some portions at its base, offered little resistance to the Röntgen rays.

The same observer, moreover, after several unsuccessful attempts, succeeded in obtaining a faint outline of the fœtus in the living uterus. The fœtal shape could be recognised, and the position of the limbs was evident, but the head was hidden by the maternal pelvis. No fœtal skeleton could be distinguished. The experimenter concluded that the fœtal body and limbs were differentiated by the rays from the darker uterine walls and amniotic fluid.

Other observers have arrived at more or less similar results.

Thus, Imbert showed at the Montpellier Congress of Medicine a record obtained from a young woman of twenty-five, in whose case Professor Tedenat had diagnosed extra-uterine fœtation. Several of his *confrères*, on the other hand, suspected a hæmatocele or a tumour. All doubt was done away with by the Röntgen photograph, which clearly showed the existence of a five or six months fœtus, of which one could see the head, the trunk, and the lower limbs.

M. Varnier showed to the Paris Society of Gynæcology and Pediatry, on March 31, 1899, a dozen radiographs showing the position of the fœtal head in the living pregnant uterus. They were obtained with exposures of three minutes.

Messrs. Chappuis and Varnier, quoted by Dr. Mandras (Paris Thesis), took a Röntgen photograph directly after death of a

* *American Journal of the Medical Sciences*, March, 1896.

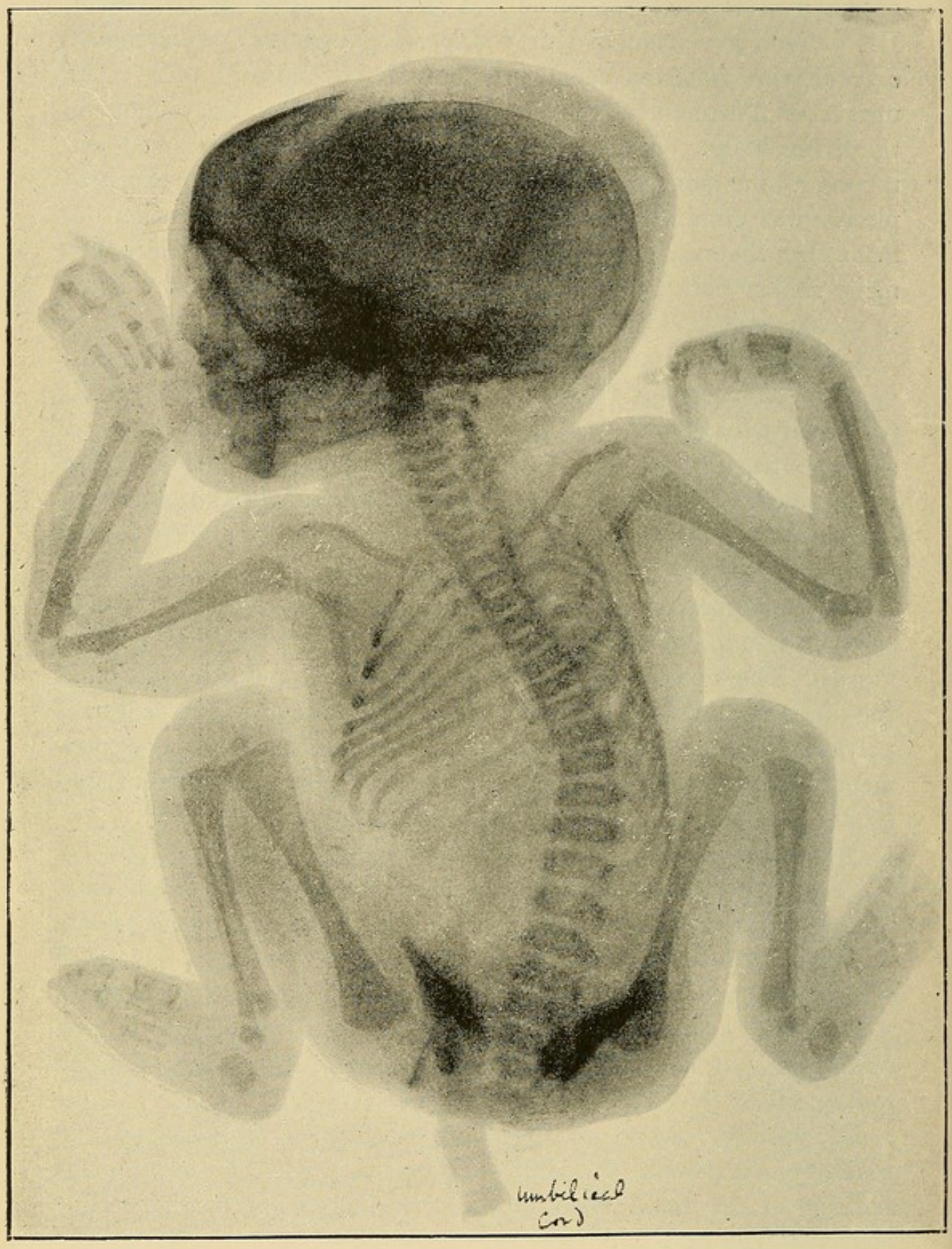


FIG. 168.—FŒTUS FROM AN EXTRA-UTERINE FŒTATION.
Dr. Oliver's case.

guinea-pig far advanced in gestation. They obtained details of the maternal pelvis and silhouettes of four fœtuses. Negative results were obtained from a chloroformed guinea-pig.

The same experimenters showed the possibility of getting good anatomical and pathological results with the rays from the gravid uterus after removal, both when hardened in alcohol and when frozen.

Messrs. Varnier and Chappuis have obtained a Röntgen-ray picture of several fœtuses in the uterus of a living guinea-pig.*

Most interesting *x*-ray pictures can be obtained of fœtal monstrosities, after removal from the body, which convey anatomical information that could otherwise be obtained only by a tedious and difficult dissection. The illustration of a two-headed fœtus shown in Fig. 169 was taken from a photograph by Mr. Lynn Thomas.

In the case of conjugate twins that survive and grow to maturity, such as the Siamese Twins and the Two-headed Nightingale, it is likely that the rays might afford pictures of much anatomical interest.

In France a special means of examining the pelvis by means of an instrument called the endodiascope was some years ago introduced by Bouchacourt. A long metal shielded prolongation of a focus tube is passed into vagina or rectum. It is open to question whether sufficiently good results cannot be obtained by less complicated procedures.

GYNÆCOLOGY.

As a rule, however, valuable information is sometimes obtainable, by means of the focus tube, as to many pathological conditions of the soft tissues of the pelvis, such as ovarian tumours, fibroids, sarcomata, and various malformations. In order to obtain such records the intestines should be empty, and the abdomen compressed with a good diaphragm.

* *British Medical Journal*, May 30, 1896.

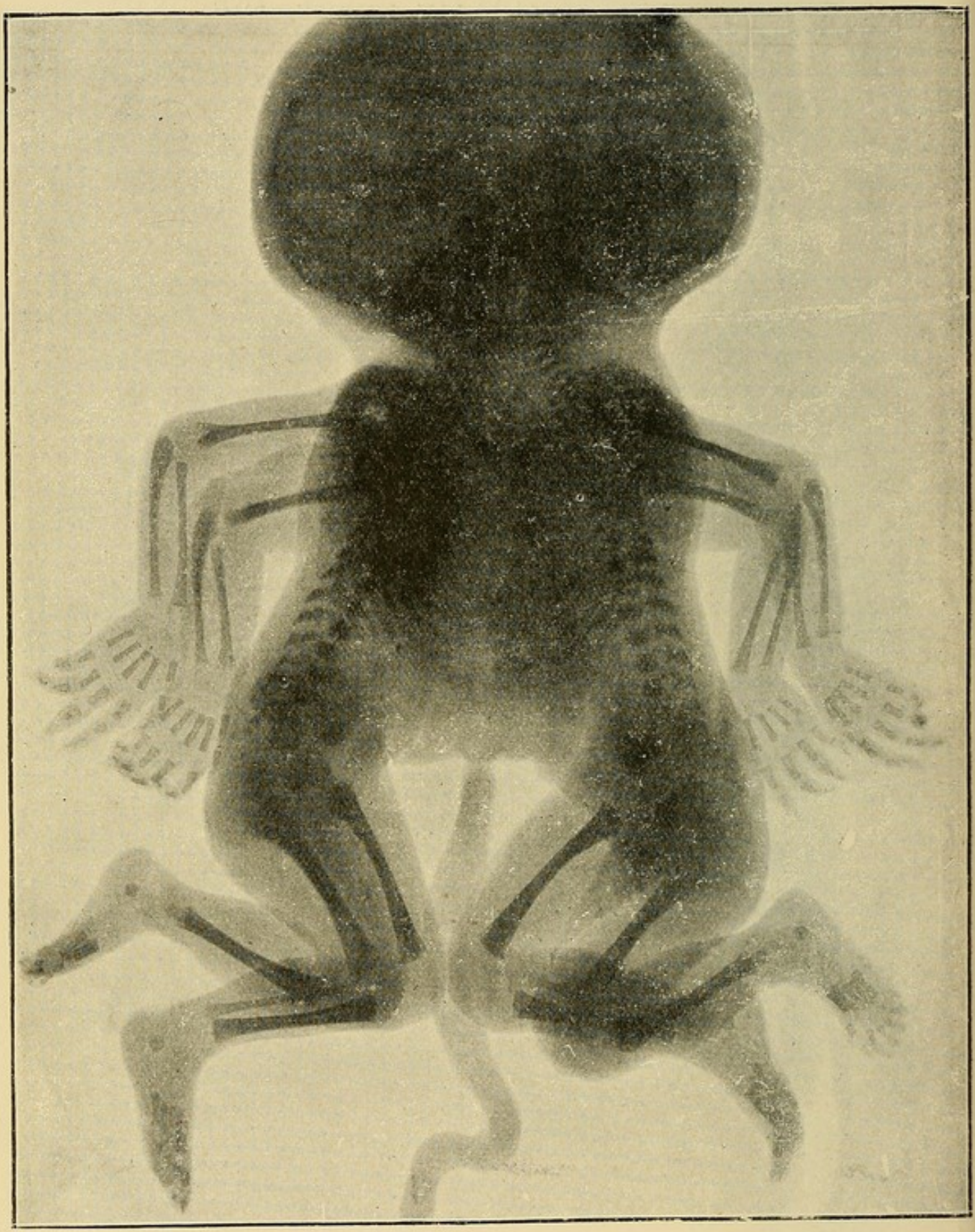


FIG. 169.—TWO-HEADED FŒTUS.
Lynn Thomas.

F. LEGAL MEDICINE

In a number of cases Röntgen-ray photographs have been produced in the law-courts. They afford evidence of fact, and corroborate or disprove opinions arrived at by ordinary methods of inference. Their special value is that exact evidence apparent to the senses of everyone concerned, be he lay or medical, is rendered available by the use of unerring scientific apparatus. With the average juryman an ounce of such fact is likely to outweigh a ton of probabilities obtained from roundabout deductions. To put the matter in another way, the testimony of a general practitioner armed with a corroborative Röntgen photograph would go far towards upsetting the contradictory statements of the most highly skilled surgeon, provided the opinions of the latter were based upon nothing more tangible than the ordinary methods of examination. The position of a juryman called upon to settle the nature of an injury in the face of conflicting skilled testimony is one of extreme difficulty, which would be in many cases considerably lessened by the help of a radiogram.

As with ordinary photographs, radiograms have been generally accepted as evidence in the law-courts of civilized countries.

The radiogram may be valuable in any of the following medico-legal points arising in civil or criminal cases :

1. Evidence of injury, or of the presence of a foreign body.
2. Evidence of bodily identification.
3. Evidence of pregnancy.
4. Evidence of age of fœtus, or of live birth.
5. Evidence of death.
6. Evidence in action for malpraxis.

I. EVIDENCE OF INJURY.

It is clear that the presence either of a foreign body, as a bullet, or of an injury to bone, such as a fracture, can be clearly proved

by means of a radiogram, which in some cases may be taken many years after the original accident or injury. Thus, a fracture often leaves a lifelong and unmistakable record of its occurrence, and a dislocation may be photographed by the Röntgen rays at any time previous to its reduction.

Already numerous cases have occurred where *x*-ray evidence has been produced in court. One such instance was mentioned in the *British Medical Journal* for June 6, 1896, where a bullet in a hand formed the object of a criminal prosecution.

A case occurred early in 1897 in Dunfermline. A boy was accidentally shot by a rifle discharged by an unseen person at a great distance. The presence of a rifle bullet buried in the boy's lung was admirably shown by a radiogram taken by a local operator. In that case the man charged was dismissed for want of exact identification with the person who fired the shot.

Generally speaking, in any action for injury due to negligence, if a bone be fractured or displaced, the plaintiff may obtain valuable corroborative evidence from a Röntgen photograph. Or the defendant, on the other hand, may be enabled to show thereby that the plaintiff's injury is exaggerated, misrepresented, or non-existent. A careful distinction must be made as to the injuries of soft tissues, which are rarely shown by the Röntgen methods, but are often just as disabling or fatal to the patient.

II. EVIDENCE OF IDENTIFICATION.

The *x*-rays may be useful in several ways in identifying both the living and the dead. For instance, they may prove the presence of former injuries, such as fractures. In the well-known case of Dr. Livingstone, the African explorer, an *x*-ray picture of the false joint in the arm due to the bite of a lion, an injury from which he was known to have suffered, would have afforded valuable corroborative evidence of identification.

Another way in which the rays might be useful would be in determining the age of a body up to early adult life, from the union or non-union of bony epiphyses. Any conclusions on this point, however, would have to be formed with a due regard to the varying ages of epiphyseal union. Observations so far show that, apart from early bone disease, there is apparently a good deal of individual difference in the time of fusion of

epiphyses. This point is dealt with more fully in a later section on Anatomy.

Professor Amoedo proposes to take the measurements of the pulp-cavities of the teeth as a test of age. He states* that in 1844 Carabelli of Vienna, Kory in 1885, and Boedeker of New York, in 1894, made investigations on this point, but were obliged to work by the laborious method of cutting sections. Thanks to radiography, however, a number of teeth may be measured exactly within a short time. He points out that the pulp-chamber of the first molar is smaller than that of the second, a fact which he attributes to its prior eruption by six years, as one knows the cavity enlarges with age.

III. EVIDENCE OF PREGNANCY.

Up to the present some uncertainty attends the diagnosis of pregnancy by the Röntgen rays—at any rate, in the early stage of the living subject. It may be stated, however, that a good picture of the fœtus may be obtained *in utero* after removal from the body. Moreover, an outline of the fœtus has been frequently obtained by several experimenters in the living subject. One result of a more perfect process would be to enable the English criminal law to replace by exact scientific methods the 'jury of matrons,' whose verdict decides whether a woman condemned to death is pregnant or otherwise. Even in these modern days, the question is on rare occasions still settled by that ancient tribunal.

IV. EVIDENCE OF AGE OF FŒTUS.

A perfect Röntgen record may be obtained of a fœtus after removal from the uterus. In this way the stage of ossification can be exactly estimated, in a way that could be otherwise attained only after a tedious and difficult dissection. Moreover, by injecting the bloodvessels with a preparation of red lead, the radiogram might be made to reveal the state of the fœtal circulation.

When medico-legal evidence is required of the viability of a fœtus, however, the Röntgen photograph is only, as a rule, of corroborative value, inasmuch as it reveals the full-term bony development or otherwise. It is never likely to supersede in any

* *Les Rayons X*, 2 Avril, 1898, p. 5.

way the evidence now tendered and accepted as to live birth, such as, for instance, the hydrostatic lung test. Viability, it should be remembered, is possible at seven months. The material things that may be readily demonstrated in court by means of a radiogram are fractures of the skull and other parts of the body, and the appearance of the osseous nucleus of the inferior femoral epiphysis, to which Husband, in his 'Forensic Medicine,' as a result of the examination of nine intra-uterine fœtuses at the ninth month, ascribes a maximum length of 2 lines. The subject of fœtal ossification is an interesting one, and no doubt the conclusions now laid down by anatomists will, sooner or later, be widely tested by the convenient Röntgen methods.

Positive *x*-ray evidence, however, as to the fact of separate existence of a child has been suggestad by M. Bordas.* On June 8, 1896, he laid before the Paris Société de Médecine Légale two Röntgen photographs of fœtal lungs which showed the presence of air-bubbles in those who had breathed, as against absolute opacity in the still-born.

V. EVIDENCE OF DEATH.

It has been proposed to apply the rays as a test of death, on the assumption that there would be increased resistance on the part of dead tissues; but it has not been found possible to carry out the suggestion in that way. The desired test, however, has been found in another direction, namely, by taking an *x*-ray observation of the heart. During life the pulsating upper cardiac margin, as seen from the back, throws a diffuse shadow on screen or negative, whereas the non-pulsating dead heart yields a sharp record, both fluoroscopic and photographic. Stereoscopically, a picture could be obtained that would be unmistakable to the veriest layman. In this way an important yet simple addition has been made to the trustworthy signs of death; and the discovery of Röntgen should thus bring comfort to those whose minds are distressed by the time-worn fables of premature burial.

VI. EVIDENCE IN ACTION FOR MALPRAXIS.

The Röntgen rays may prove of great value to the protection of medical men, when otherwise it might be difficult to meet a

* 'Technique des Rayons X,' A. Hébert, Paris, 1897, p. 105.

charge of negligence. Experience has long since shown that in many cases a surgeon needs protection no less than a patient, for he is not infrequently charged with having overlooked a fracture or a dislocation, when as a matter of fact no such injury was present.

In one instance the present writer was called upon to make a Röntgen ray examination in an action brought against a medical man for negligence in overlooking a broken rib or ribs. The plaintiff, an elderly, stout, asthmatic man, had been thrown out of a vehicle, and fell lengthwise, with his right nipple line along the edge of the kerbstone. As the alleged injury was in front of the body and over the site of the liver, it was found impossible to photograph the ribs in that position, although the writer has since succeeded in getting a perfect picture of the front ends of the lower ribs in a living adult man of average build. Although the result proved negative, so far as the plaintiff's ribs were concerned, it nevertheless revealed the fact that he was suffering from aneurism and from bronchiectatic cavities of the lung. The existence of the aneurism, by the way, was denied by the plaintiff's physician, but it should be noted that in so large a chest it would have been wellnigh impossible to discover, under the particular circumstances, the aneurism by any means other than the rays. The plaintiff failed to bring any positive evidence as to the alleged fracture, and his case broke down.

As regards one branch of irregular or quack medical practice the *x*-ray photography is likely to do yeoman's service. The bone-setters are a fraternity who batten on the ignorance and the credulity of their victims. Their almost invariable plan is to tell the sufferer that a 'bone is out,' or is 'broken,' or 'has not been properly set.' They declare the joint is dislocated, and break down adhesions by a sudden wrench. The truth or otherwise of their assertions can be ascertained by *x*-ray examination.

Mr. Howard Marsh has observed of the method: 'It would have furnished valuable information to a patient met with some years ago, who had slight lateral curvature of the spine. This patient was told by a bone-setter that "his pelvis had opened, and both his hips were out." The reassurance and the mental calm which a Röntgen photograph could now bring to anyone who, having nothing seriously wrong, had been told he was the subject of such a formidable condition of things, can be easily imagined.'

It may be hoped, then, that the Röntgen rays will help to rid the

world of these harmful social parasites. Sooner or later the strong hand of Science must infallibly cut the ground from under the feet of all such pretenders.

MEDICO-LEGAL.

Focus-tube Burns in Court.

Several important trials have taken place in which damages have been claimed for injuries due to Röntgen-ray exposures.

In England a case was investigated at Hastings. The following account is taken from the *Lancet* of December 8, 1900, and its substantial accuracy is vouched for by the present author, who paid a special visit to Hastings in view of the importance of the issues involved. Speaking generally, it may be remarked that the trial impressed one with the necessity of expert help on both sides of an issue of the kind. It also shows the advantage of entrusting cases for Röntgen-ray examination, wherever possible, to a medical operator, who would be alive to any contingent risks, and who would share responsibility with the medical attendant.

'The recent case,' writes the *Lancet*, 'in which the Röntgen-ray methods caused an injury preceding death, raises points of great practical importance to the medical profession as well as to non-medical operators with the rays and to the outside public. The following facts were deposed to before the coroner, Mr. Davenport Jones, at the adjourned inquiry held in the Hastings Town Hall on November 17, 1900.

'On March 21 last a widow lady, aged sixty-eight years, met with an accident to her left hip while learning to ride the bicycle. She was taken to the local hospital, where the opinion was expressed that no fracture existed. She was then removed home, and was attended by Mr. Harry R. Mansell, who could not make up his mind at the moment that the hip was fractured. After watching the case for some time he thought that it would be advisable to clear up matters by applying the Röntgen rays. This was done, with the consent of the deceased, by a local photographer, Mr. J. H. Blomfield, on April 14, when two exposures were made, according to the operator's statement, one of thirty-five and the other of forty-five minutes, each hip being taken separately. The result was not considered altogether satisfactory by the local medical society, and it was suggested a further photograph to show both hips should be taken from the centre of the body. This was accordingly done, with the consent of the deceased, on April 27, by the same photographer, with an exposure of forty-five minutes. On both occasions Mr. Mansell attended and gave directions as to the position of the patient, but afterwards left the house and entrusted further details to the photographer. On the first occasion, according to Mr. Blomfield, the part of the body exposed was covered with clothing, but on the second it was bare. On May 4 an eruption

developed on the left lower abdominal region. This was recognised by Mr. Mansell as an *x*-ray injury, and was treated with ointment, but the dermatitis developed into an ulcerated surface of the size of the hand. On July 5 the deceased declined further attendance from Mr. Mansell, and called in Dr. J. H. Roberts. The latter brought Mr. A. R. Ticehurst in consultation, and attended the deceased until her death on November 5. On July 7 Dr. Roberts found her to be suffering from a sloughing wound about 7 inches by 3¼ inches. Death, in his opinion, was caused by exhaustion from the effects of shock, which resulted from two injuries—the fracture of the thigh and the action of the Röntgen rays. Mr. Ticehurst, who visited the deceased in consultation, and who subsequently performed a post-mortem examination, stated that when he saw the deceased alive on October 5 he found her to be suffering from a dry sloughing wound of the abdomen. At the necropsy the wound had lost its slough, but there was little sign of repair. There was little fat about the body, the heart was flabby, the stomach was empty, the liver showed signs of old mischief, the vessels were degenerated, and he found an impacted, intracapsular fracture of the neck of the femur. Mr. Ticehurst would not say that the condition of the body would be sufficient to cause death apart from the wound. The niece of the deceased stated that her aunt's mind gave way several weeks before her death, and she refused food, which had to be forced upon her by the nurses. The photographer, Mr. Blomfield, stated that he had had four or five years' experience with the rays, part of the time at the Hastings Hospital, and had met with no injurious effects from similar prolonged exposures. Dr. Lewis Jones, in charge of the electrical department of St. Bartholomew's Hospital, gave evidence to the effect that he had seen the apparatus used by Mr. Blomfield to take the photograph of deceased. There being no rash between the first and second exposures, he would consider a medical man right in assuming that the patient was not sensitive to the rays. The risk of an *x*-ray burn was always present in long exposures. The apparatus use by Mr. Blomfield was a year and a half out of date. In default of a better instrument, the one used was a proper one. It gave a 10-inch spark, and a similar one was in use at St. Bartholomew's Hospital until a year and a half ago. He himself had given exposures of forty minutes, but the usual length of time was seven or eight minutes. Short exposures were less likely to cause burns than long. At the time when the photograph was taken Mr. Blomfield's coil was working at 5½ inches. The coroner summed up, and the jury returned a unanimous verdict: "That the deceased met her death from shock and exhaustion following the accident and the effects of the Röntgen rays upon a weakened system. No blame attached to either the medical man or the photographer." '

With regard to this case, it may be remarked that the fact of the friends of the deceased not having been represented by expert evidence detracts somewhat from the value of the inquiry. It was admitted that

no note was made of the time of the exposure, the distance of the tube from the plate, and other details that cannot safely be left to the memory. From the evidence it is clear that a burn resulted from prolonged exposure to the focus-tube, probably from the third exposure of forty-five minutes on April 27, as the rash appeared seven days after that date. However, the fact that the first exposures were not followed by dermatitis during the thirteen days that elapsed does not absolve those exposures from all blame. It is reasonable to assume that the degenerative changes in the body of the deceased were indirect factors in the causation of the burn just as they were in the fracture of the hip.

Unfortunately, for reasons already stated, the full details of the exposures are not available. At the same time we are told of one important differing condition of experiment—namely, that the surface of the body was not protected by clothing on the third exposure, the one from which the damage in all probability resulted. No mention was made of the crucial point of the distance of the focus-tube from the skin. Nor was the fact made clear to the court that a 10-inch coil working at 5½ inches is reduced almost, if not quite, to the lesser value. The bearing of this upon the length of exposure is obvious. With his coil working at 10 inches Mr. Blomfield could have almost halved his exposures, and the focus-tube burn is distinctly related to the length of exposure. The reasons for a coil not working up to its full strength are various, but all are open to remedy. The mention of these facts will show the desirability of having expert evidence on both sides of so highly technical an inquiry.

As regards the responsibility of a medical man who engages a non-medical man to take a Röntgen photograph, the matter is not advanced by this case. The fact that the patient consents to the photography can hardly absolve the medical attendant. If the latter hands over the operation to a non-medical man, it is a question of how far he is relieved of responsibility. A chemist is responsible for errors in dispensing a prescription, but he is licensed to practise pharmacy, whereas the electrical or photographic worker with the rays has no such recognised and tested legal status. If the non-medical photographer had undertaken the case for the local hospital, what would have been the position of the committee of that institution in the matter? On the other hand, the employment of a medical Röntgen ray expert would clearly absolve a medical man of further responsibility. Any medical operator must have hesitated to expose to the rays for forty-five minutes an old lady who had been laid up for five or six weeks with a broken hip. It seems undesirable, moreover, that female patients should be submitted to the manipulation of instrument-makers and other non-medical workers with the rays. The moral of the case appears to be that apparatus should be up-to-date, and that medical men will act wisely in sending their cases to medical Röntgen-ray experts, of whom there are a fair number available.

In the United States a suit was brought for $25,000 damages against Dr. Otto Smith and Professor W. C. Fuchs, of Chicago. A summary of the case appears in the *American X-Ray Journal.**

The plaintiff, aged thirty-seven, broke his right ankle as the result of an accident from his buggy on September 2, 1895. He was able to attend to his lumber office and yard by May 1, 1896, and was then practically as well as before the mishap. He suffered, however, from slight stiffness and occasional swelling in the ankle. On September 19, 1896, '*x*-ray photographs were made'—the exact number not stated—'occupying from thirty-five to forty minutes, by placing the tube from 5 to 6 inches from the ankle, the tube being about the same distance from the top of the foot.' While under the exposure he experienced and complained of sharp tingling pains. Three days after a slight redness appeared between the big toe and the first toe, which in three weeks had spread to almost the entire surface of the top of the foot, and later formed a blister. An ugly-looking and intensely painful ulcer formed, for which condition amputation of the foot was performed. The jury awarded $10,000 damages.

In France an important trial heard before the Civil Tribunal of the Seine on March 8, 1901, resulted in heavy damages for injury following the application of the Röntgen rays.† In delivering judgment the court found that Madame Macquaire, who suffered from osteitis of the femur, was handed over early in 1898 by Dr. Rousseau to Dr. Renault, in order that the latter might make a Röntgen-ray examination. Three exposures were made: the first of forty minutes, the second of forty-five minutes eight days later, and the third of an hour and a quarter fifteen days after the second. A slight erythema was noticed before the third sitting. The three exposures, which were negative as regards diagnosis, were followed by a deep burn of the abdomen that necessitated treatment for upwards of two years. A scientific report of the case was presented to the court by Professor Brouardel. Among other things, he concluded that the operator had an apparatus which was formerly good, but had become bad, and that he had given too long an exposure. The court, commenting on the defective methods employed, observed that the defendant was called in, not as a medical man, but as an electrical specialist, but that, nevertheless, his medical title had gained the confidence of his clients against bad results. A too long exposure was certainly one cause of the accident. The third exposure of an hour and a quarter was inexcusable (*inadmissible*), in view of the fact that the tissues had been already injured by a previous exposure of a little over half that time. The conclusion of the court was that Dr. Renault had committed a grave professional error, and he was ordered to pay damages to the extent of 5,000 francs.

* *American X-Ray Journal*, St. Louis, Mo., May, 1899, No. 5, p. 566.

† See *Gazette des Tribunaux*, March 9, 1901; and *La Semaine Médicale*, March 13, 1901, p. xlii.

An interesting case* tried in Providence, R.I., emphasizes the value of experienced medical testimony either in supporting or in rebutting evidence based upon Röntgen ray photographs. The plaintiff, a woman, brought an action for $4,000 damages. Two years before she sustained an injury of the wrist, which was treated as a Colles's fracture. At the time it was held by some of the medical men consulted that the injury was a Barton's fracture—that is to say, an oblique fracture of the radius extending from the joint. Radiograms were produced on both sides. Those of the plaintiff showed a characteristic deviation of the hand to the radial side, but the defendant contended that this deformity was assumed for the purpose of deception. For the defendant, Dr. Green said that about 1 inch from the carpal end of the radius there were slight prominences extending laterally from the shaft of the bone, a point corresponding to the site of Colles's fracture. According to his evidence, Barton's fracture was not confirmed by the *x*-rays. Adopting that view, the court dismissed the case.

In commenting upon the foregoing trial, the editor of the *American X-Ray Journal* remarks that from the report of the case it is not possible to resist the feeling that the evidence was insufficient to prove a Colles's fracture, and lacking in *x*-ray expert testimony to disprove a Barton's fracture.

'The report of this case,' he writes, 'does not read as if the evidence was all brought out. In the *x*-ray examination the writer would judge that the radiograms of the hands were taken in opposite directions on the same plate. It is a well-known fact that the right and left hand and forearm laid evenly and opposed will not show corresponding space between the bones of the carpus and the radius. If the physician understands anatomy and radiography very well, he can at will distort a normal joint in a picture, or favourably present the condition of an injured one. The normal divergence of the *x*-rays, which is constant always to some degree, makes the picture untrue. The distortion by position can be of almost any degree, and with an operator who is an expert we must rely on his oath. If he is not an expert, his testimony is faulty. It was not shown in this case that *any means were taken to obtain parallelism of the x-rays.*'

In Austria heavy damages have been awarded against a medical operator. After several trials the case terminated in the summer of 1906. A patient who suffered from chronic psoriasis was sent by Professor Lang to Dr. Holzknecht, chief of the *x*-ray department of the States Hospital of Vienna. The latter applied the treatment first in 1902, with the result that later the patient was laid up with a severe burn. The judge awarded the plaintiff 30,000 kronen (about £1,200) damages, and 5,000 kronen (about £200) for personal expenditure. The court came to the conclusion that the defendant had neglected to explain to the patient

* *American X-Ray Journal*, May, 1899, No. 5, p. 568.

the risk of a method which was at that time (1902) to be regarded as in the experimental stage, and that only Dr. Holzknecht was responsible, as he was the expert on electro-therapeutics, whilst Professor Lang, the dermatologist, who had merely suggested the method, could not very well foresee its effect.

In consequence of that trial Dr. Holzknecht invented a radiometer, whereby the dosage of *x*-rays can be accurately measured in any given case.

In a case at Bournemouth (Ellis *v.* Bridge), on July 13, 1906, plaintiff claimed damages against a well-known local chemist for personal injuries. He suffered from locomotor ataxy, and upon the advice of his medical man, Dr. Ord, went to Messrs. Bridge and Co. for a course of *x*-ray treatment, which was applied by a non-medical operator, Mr. Keene, a director of the firm. Serious burns resulted. The exact distance of the tube from the feet was not determined; the plaintiff said it was 4 inches and defendants 12 inches. The jury found there was no negligence, and judgment, with costs, was given for the defendant.

In this case the defendants, Bridge and Co., sought to throw all responsibility upon Dr. Ord, who appears to have taken only a general supervision of the treatment. The whole trend of British law appears to be in favour of non-medical persons who assume medical functions. Anyone possessing medical knowledge would apply *x*-rays with the utmost caution to a patient suffering from locomotor ataxy. If the law permits the application of so powerful a therapeutic agent as the Röntgen rays by an unqualified person, then the sooner it is amended the better for the public.

In an Irish case an action, M'Callagh *v.* the President and Professors of Queen's College, Galway, failed to recover damages for a burn caused by an *x*-ray examination by a non-medical operator.

In the case of Cloete Smith *v.* Parr the plaintiff, a medical man, claimed £100 for professional services. The wife of the defendant had undergone an operation for malignant disease, and went under Dr. Smith for high-frequency electrical treatment. Without consulting defendant, *x*-ray treatment was substituted, and the patient became severely burnt. The jury found that the defendant did not consent to the plaintiff's treatment, which was improper, unskilful, and negligent, and found a verdict for the defendant on a counterclaim of £100.

In 'railway spine'—a form of injury that figures largely in the law-courts—an *x*-ray examination is at times useful. In a remarkable case some years since Mr. Openshaw, of the London Hospital, obtained evidence of fracture of the vertebræ in a patient who alleged injury in a railway collision.

Cosmetic Effect of the X-rays.

Due protection of the surrounding area must, of course, be provided when treating cases simply from a cosmetic standpoint. Omission in this

respect may entail an action for damages on the part of the patient should any dermatitis supervene. In a case of this nature, narrated by Carl Beck,* the plaintiff recovered $75. It is otherwise, however, in malignant disease, where a more destructive effect is desired.

Action for Malpraxis.

A Miss Jameson, of Great Works, Me., claimed damages against Dr. G. G. Weld, of Old Town, for $4,000 on account of alleged malpractice in setting her dislocated right elbow.†

The plaintiff, after an accident, was attended by Dr. Weld, who called two other medical men in consultation. After some days, as treatment afforded no relief, the patient suggested the use of the Röntgen rays. Dr. Weld, according to plaintiff's testimony, declined, because he knew the nature of the injury—namely, fracture of the olecranon, fracture of both condyles, and dislocation. The patient went to a hospital, and a Röntgen-ray photograph, admitted in evidence, revealed no fracture, but a backward dislocation, which was successfully reduced. The *x*-ray picture was the conclusive factor in this case, for it showed the condition of the arm at the close of the defendant's treatment. The jury found a verdict for plaintiff.

Malingering.

Dr. Baehren, of Wiesbaden, published the case of a soldier who was treated for a swollen finger and sinus of the third metacarpo-phalangeal joint. On *x*-ray examination five needles were seen in the interosseous space, but next day only four. The man afterwards admitted he had introduced the needles himself in order to escape military service.

Proof of Innocence.

Carl Beck‡ narrates the case of a Russian recruit who was accused of having produced himself a condition of œdema of the foot, accompanied by tarsal thickening. There was a history of previous injury a year ago. He was unable to engage in active service on account of the pain, and was sentenced to three months' solitary imprisonment for self-mutilation. A skiagraph was at last permitted, when it was found that the unhappy man had sustained a fracture of the astragalus. The prisoner appealed to a higher court, and was declared to be unfit for military service upon the finding of the skiagraph.

* *Medical Record*, February 20, 1904, p. 292.
† *American X-Ray Journal*, May, 1899, p. 569.
‡ *Medical Record*, August 9, 1902, p. 202.

Life Insurance.

Mr. F. H. Williams* has pointed out the value of the rays in life insurance examinations—at any rate, so far as concerns abnormal conditions of the chest. It may be added that a negative result might enable a rejected applicant, or one who had been highly rated, to dispute the decision.

Copyright in Radiograms.

A medical man wrote to the *Lancet*† complaining that he had sent a patient to have a radiogram taken by an instrument-maker, who had afterwards, without his sanction, supplied a copy to another person, and sent a representative to a public meeting to explain the plate. The *Lancet*, commenting upon this occurrence, expressed a strong opinion upon this breach of trust in using a radiogram without obtaining the leave of the patient and the medical man. In a later issue of the same journal‡ Dr. Major Greenwood said there was little doubt that a man who takes a radiogram for a customer is acting illegally if he makes any use of it contrary to the wish of that customer, and could be restrained at law from so doing. That was decided in 1899 in the case of Pollard *v.* Photographic Co. (40 Ch. D., 345), where it was held that a photographer may not sell, or exhibit, or otherwise deal with, the photographic negative of a private person who has employed him to take a photograph. That decision would clearly apply to the case of a radiographer.

HINTS IN PREPARING EVIDENCE.

In seeking Röntgen-ray evidence, it is clear that the wisest course will be for the lawyer to go at once to a skilled medical operator. There is no process that needs more accurate general and special knowledge than that involved in preparing *x*-ray medical evidence. Pitfalls await the unwary or the non-medical witness on every hand, as he and his principals may find to their cost on his appearance in the witness-box. The following hints may possibly be of some service to those who are called upon to furnish legal evidence of the kind:

Make a note of patient and of his case, with full details, such as name, address, date, history, and symptoms. If possible, make the examination in the presence of the medical man or

* *Boston Medical and Surgical Journal*, December 28, 1899.
† November 4, 1899, p. 1274.
‡ November 11, 1899, p. 1343.

men engaged on the opposite side. All notes to be reduced to writing at the earliest opportunity.

Never neglect to make a screen as well as a photographic examination.

Make an identifying mark (to be entered in notes) on all photographic plates. Keep all negatives and photographs under lock and key, and under no circumstances allow the originals to leave your possession. Neglect of this precaution may lose a suit.

Remember that the Röntgen method reveals mainly injuries to bone, whereas soft-tissue damage may be quite as disabling to the patient.

The necessity for obtaining *at least two* skiagraphs of a fracture from different aspects should be borne in mind, as frequently loss of continuity can only be determined in this manner.

Be careful to guard against fallacies such as those due to position of parts in relation to the tube. This can be done by having comparative photographs of the corresponding sound parts ; indeed, that should be the invariable rule in legal cases. Wherever possible, make an exact localization.

Sometimes firm union occurs in a fracture, although the Röntgen photograph may not register bony union for many months afterwards.

An ununited epiphysis may be mistaken for a fracture, or the injury disclosed may be one of old standing.

Negative evidence, *e.g.*, the absence of a bullet, is often as valuable as positive.

Think out all the points of the case, and make no statement which you cannot justify in the witness-box. Carefully sift out matters of fact from matters of opinion.

It is well to have an understanding as to the amount of fee to be tendered for expert evidence before attending court. In one ease brought to the attention of the writer, a medical operator was appealed to *ad misericordiam* to accept a nominal fee in an action brought against a brother professional ; the latter won the day, and costs fell upon the other side, but no increase was made in the sum first agreed upon.

G. ANATOMY

A GOOD deal of light has been already acquired in relation to the age at which union of bony epiphyses takes place. It appears certain, for instance, that the variation of the individual in this matter is much wider than hitherto recognised by the anatomists. The method offers obvious advantages in obtaining data for general conclusions as to ages of ossific union. It would be more rapid and accurate than the tedious observations to be gleaned from the alternative plan of laborious dissections. Moreover, the rays could be applied to the living as well as to the dead, and also to bodies where post-mortem examination would be impossible.

In the first volume of a beautifully-illustrated Röntgen-ray atlas of normal and pathological anatomy,* Professor Lambertz gives a detailed account of the ossification of the skeleton from its earliest appearance in the embryo up to the period of birth. There are many admirable illustrations.

The second part deals with the upper extremity. It gives many interesting examples of congenital defects, such as fœtal amputations, brachydactylism, hyperphalanxism, and polydactylism.

ANATOMY OF BLOODVESSELS.

The injection of bloodvessels by some material opaque to the rays, and their subsequent study by the rays, opens up a wide field of anatomical investigation. In this way Dr. F. J. Clendinnen, of Melbourne,† demonstrated the arteries of a seven-months fœtus, which he had injected with a solution of red lead. His record afforded a sharp and beautiful diagrammatic view of the

* 'Atlas der normalen und pathologischen Anatomie in typischen Röntgenbildern.' Hamburg: Gräfe und Sillem, 1900.

† *International Medical Journal of Australasia*, October 20, 1896, p. 611.

arteries, even where they passed behind the fœtal bones. A peculiarity such as that of double high division of the brachial artery was well shown.

In a later issue of the same journal (January 20, 1897), Dr. Clendinnen published some further illustrations obtained in a similar way. They showed the arteries about the knee and the ankle joint. The small muscular twigs and other minute branches were reproduced with the utmost fidelity.

There can be no doubt that this method may now and then afford a valuable means of showing in a graphic manner the

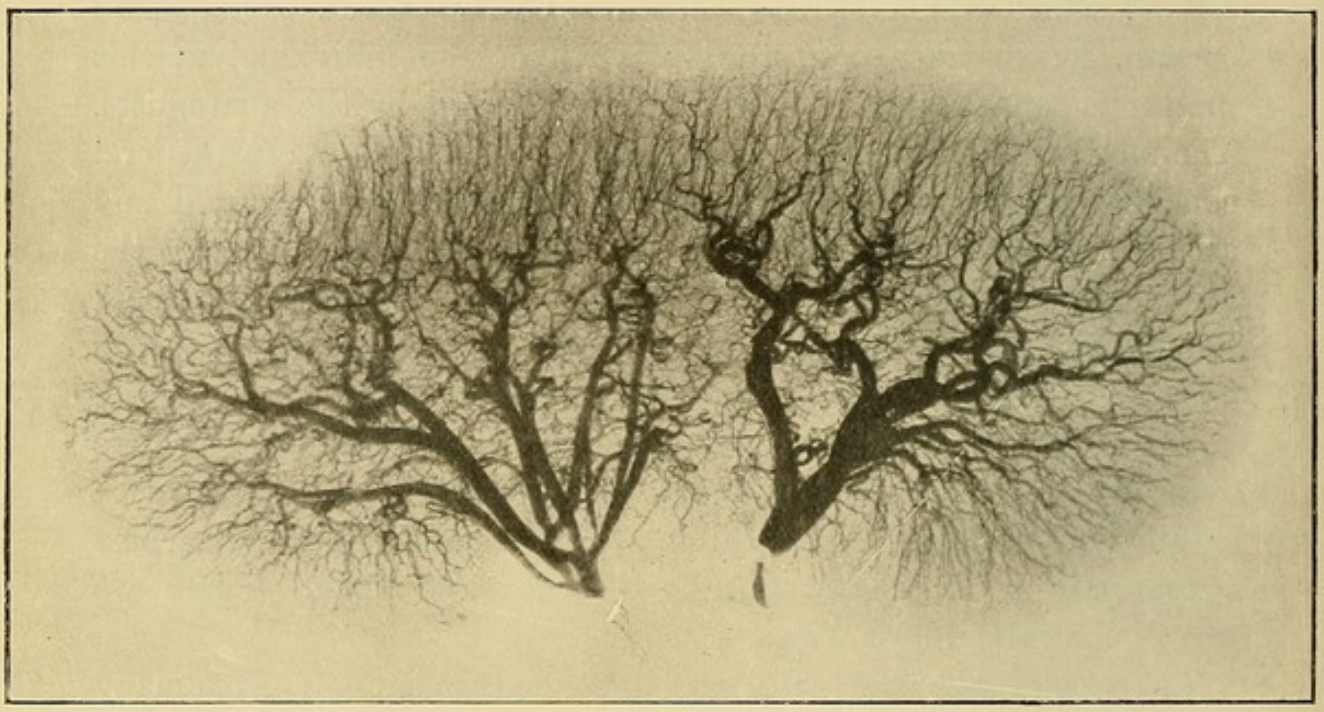


FIG. 170.—INJECTED BLOODVESSELS OF HUMAN KIDNEY.

By Dawson Turner.

facts of local blood-supply, both in normal and in pathological specimens. As an instance of the latter, a perfect picture could be obtained of circulation by anastomoses, say, in a case where during life the femoral artery had been tied for aneurism, or in the stump of an amputated limb.

Dr. Clendinnen adds that in one case he obtained from the living body a good record of the popliteal artery. This observation is valuable, and perhaps points to the time when a fuller knowledge of conditions in relation to results will bring the blood-vessels under command of the Röntgen-ray worker.

At a meeting of the Biological Society of Paris, June 11, 1898, M. Turbert* showed two radiograms, the first of which, taken from a dead body, showed clearly the radial and ulnar arteries; and the course of these arteries could be followed even where their radiographic shadow was superimposed upon that of the bone. The vessels had not been injected in that case nor in the second, which showed the interior tibial artery for the greater part of its course in he foot of an old man.

An extensive series of investigations has been made by Mr. W. Smith† upon arteries injected with vermilion. One of an amputation at the lower end of the thigh shows well the reduction of the trunk of the femoral artery to a slender vessel.

An extremely good radiogram of a five-day-old infant injected with liquid mercury has been published by Dr. A. V. L. Brokan, of St. Louis.‡ 'To the anatomist,' he writes, 'the study of injected vessels is particularly interesting, the relationship to the osseous system showing far better than some dissections.'

Dr. Nathan Raw showed to the Manchester Pathological Society, in December, 1896, Röntgen photographs of arteries injected with plaster of Paris and carmine.

Another application of this principle of opaque injection was brought forward by Poncet,§ of Lyons. He presented the Academy of the town mentioned with a series by Destot and Bérard, showing the arterial and venous circulation of the kidney in various pathological conditions of that organ.

Some of the interesting conclusions as to normal vascular supply may be quoted. Thus, it was found that the circulation in the kidney is lobar and terminal, and permits the differentiation of an independent anterior and posterior kidney, except the artery of the superior lobe, which often divides into two branches, so that, when it is injected, the entire upper portion is permeated. Professor Dawson Turner has kindly allowed a reproduction of photographs of an injected human kidney and heart (Figs. 170 and 171), prepared by the slow injection of an ordinary dissecting-room preparation made rather thin.

A series of beautiful injections of bloodvessels by Mr. A. J.

* *Lancet*, June 25, 1898, p. 1788.
† *American X-Ray Journal*, December, 1898.
‡ *Ibid.*, August, 1898, p. 358.
§ *Gazette des Hôpitaux*, December 31, 1896.

Fryett, F.R.M.S., of Melbourne, Australia, has been published in the *Archives of the Röntgen Ray*, No. 49 *et seq.*

Some beautiful and instructive views of the circulation in

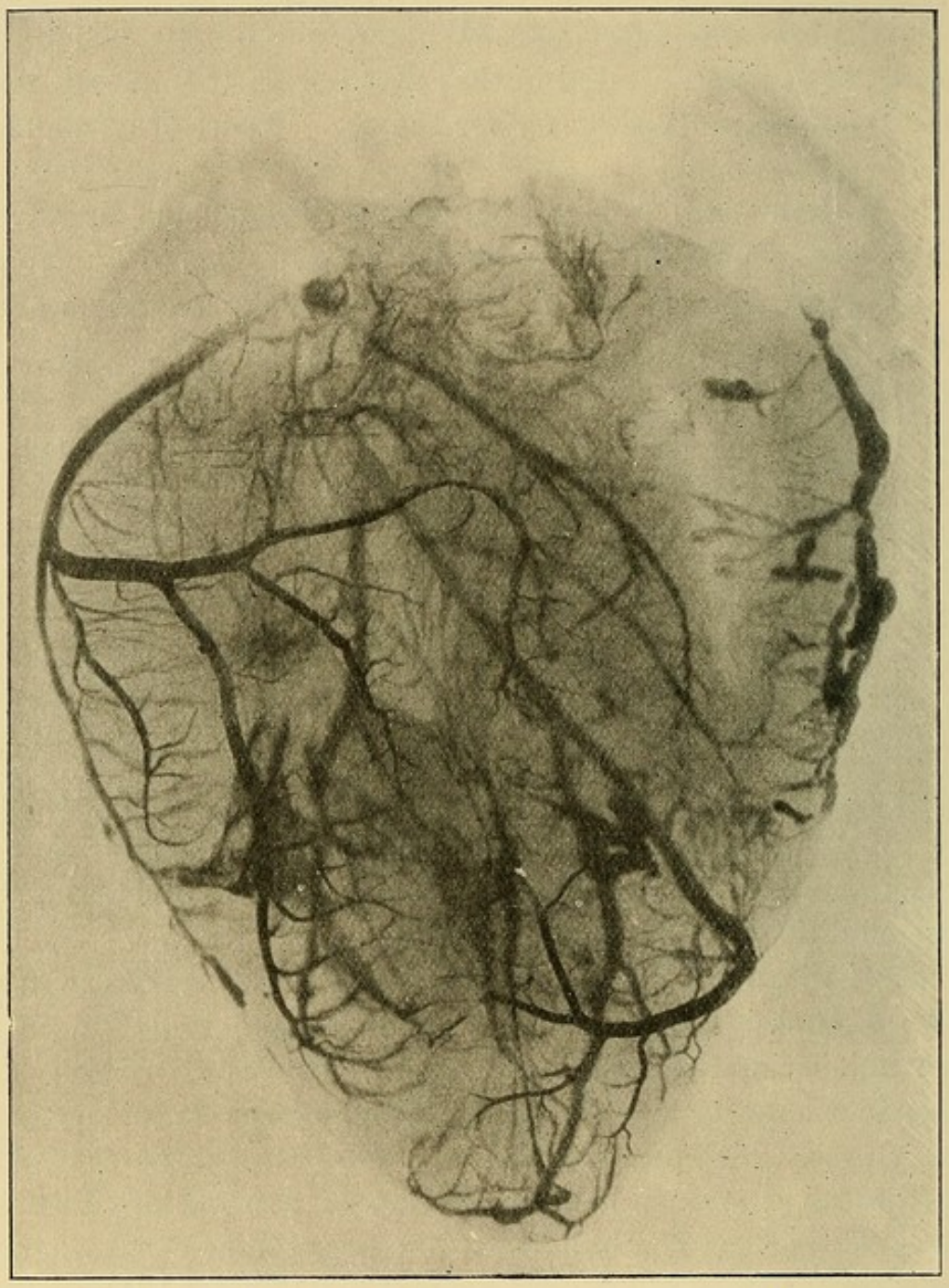


FIG. 171.—INJECTED BLOODVESSELS OF HUMAN HEART.

By Dawson Turner.

internal organs, such as the brain or the liver, may be obtained by stereoscopy.

The bearing of researches of this nature upon the study of the evolution of organs is obvious.

Another field in normal anatomy is the relation of parts in the various internal regions of the body. The exact relation of the bladder and urethra, for instance, might be studied by filling the organ and passages with melted paraffin, holding in solution some opaque mineral substance, as zinc or lead oxide.

In pathological anatomy it is possible that not a few points of interest might be solved by injecting the hollow viscera with opaque solutions, and then taking a radiogram of the result.

Blake* studied the relation of the trachea and bronchi to the thoracic walls in the cadaver. He hardened with formalin, and injected a metallic alloy into the trachea and bronchi, which he then examined with the rays. He concluded that the trachea lies in the right sternal line at its bifurcation, a point that corresponds with the right side of the intervertebral disc between the fourth and fifth dorsal vertebræ. The point, however, is influenced both by respiratory movements and by the position of head and neck: in front it is just internal to the junction of the lower border of the second costal cartilage with the sternum in adults, and under the right border of the sternum at the level of the third costal cartilage in children.

Brain.

The topographical relations of the brain, the frontal and maxillary sinuses, and the venous sinuses of the dura mater to the walls of the skull have been studied by Drs. Paul Regnier and Jules Glover. A translation of their article on the subject will be found in the *Lancet*.†

They can hardly be said to have made any new observations, but they confirm and bring out various points in an interesting manner. It may be noted that, for their anatomical preparations, they used sections of the heads of young subjects in whom the cranial sutures were not yet anchylosed. In order to preserve as far as possible the exact relations of the brain to the skull, the specimen was injected with formol through the carotid artery. This was repeated two or three times at intervals of one or two days, so as to harden the brain *in situ* without appreciably changing its shape or size. An antero-posterior section was made some weeks later through skull and brain. The cerebral hemisphere was then taken out, and the pia mater removed, as the presence of that membrane prevents a sharp record of the convolutions upon the sensitive plate. Injections of the venous sinuses were made with bronze powder held in suspension either in a solution of wax or else in tallow. The distance of

* *American Journal of Medical Sciences*, March, 1899.

† *Lancet*, February 24, 1900, p. 525.

the tube from the plate was always 45 centimetres (18 inches), and exposure varied from ten to forty minutes. The results of these investigations were reported to the Paris Academy of Medicine, August 10, 1897. Illustrative radiograms are printed in the *Journal des Practiciens* of September 4, 1897, and in *La Radiographie*. The authors are careful to point out that allowance must be made for distortions.

Their main conclusions are that it is possible to superpose upon the photographic plate the outline of the cranial sutures and of the cerebral fissures and convolutions. The outlines of the lateral ventricle can be traced. The relations of the venous sinuses, especially of the lateral sinus, to the skull can be defined both in the child and in the adult. The extremely variable form of the cavities and bony cells of the bony sinuses can be studied. The exact position of the three levels of the base of the skull can also be ascertained with regard to the outer skull. The opaque triangular base of implantation of the petrous on the squamous portion of the temporal bone can be demonstrated. The authors corroborate the observation that in some cases the lateral sinus corresponded with the anterior, the centre, or the posterior part of the mastoid. They mention a clear patch seen by the fluorescent screen normally in the head of young infants, and corresponding with the median portion of the brain. They say that this normal transparency is certainly more perceptible in the pathological state when the ventricle is dilated with fluid.

H. PHYSIOLOGY

INTERESTING results have been obtained by Messrs. Hébert and Bertin-Sans from the study on the screen of the movements of joints, more especially in the case of the wrists. The observations will no doubt be sooner or later considerably extended.

A number of interesting observations have already been made upon the movements of the heart, and also upon the varying relationship between the pulsating heart and the diaphragm.

M. Bouchard* has reported marked dilatation of the auricle when the intrathoracic blood-pressure was raised during inspiration. The same condition could be artificially brought about by endeavouring to inspire with the glottis shut, and occurred naturally during the violent inspirations of a paroxysm of whooping cough. He also noted a clear space between the heart and diaphragm during forced, but not during ordinary, inspiration.

Schott† found it easy to cause transient dilatation of the heart by hard muscular exercise.

Wherever in the interior of the body there is pulsation in any organ open to the *x*-rays, the process of chrono-photography will be available. The possible presentation of a pulsating human heart upon a lantern screen, speaks volumes for the achievements of latter-day science.

Dr. Macintyre has produced cinematographic views of the human body. This branch of the subject is likely to be greatly advanced when it is possible to take flash exposures of deep adult structures.

Professor Benedikt, of Vienna, has found that movements of the heart are best studied in young or emaciated subjects. He

* *Lancet*, September 10, 1898.

† *Deutsch. Med. Wochen.*, vol. xxviii., p. 495, 1897.

noted during cardiac systole a shortening between apex and base, and concluded there was only a systolic lateral apex impulse. Further, during systole the heart is not entirely emptied of blood, for a shadow cast by residual blood is recognisable. The bloodless heart is relatively transparent, but even thin layers of blood cast a shadow. These observations certainly seem to upset Skoda's teaching that the apex beat is due to the resistance of the blood.

One of the most interesting investigations in physiological movements has been made on the fluorescent screen by Scheir, of Berlin, who reported his results to the Congress of Medicine in August, 1897. If the rays passed through the head laterally, the naso-pharyngeal space and upper part of the pharynx were seen as clear shadows, and if the person under examination uttered a vowel sound, the velum was seen to be raised and to take up a position in the naso-pharyngeal space, varying according to the nature of the sound. With the vowel *a* the velum was raised the least, and was successively raised more and more by the succeeding vowels *e*, *o*, *u*, *i*. The velum was more raised in high than in low tones. The form of the mouth in the pronunciation of the different consonants could also be plainly seen. The shape and position of the tongue, the lips, and the jaws could also be distinguished. The rays clearly showed the movements of the larynx, velum, and other parts in swallowing, breathing, and sneezing, and in pathological conditions the irregularities could be determined with precision.*

Messrs. Sabrazès and Rivière in 1897 announced to the Paris Academy of Science that the rays had no influence either upon the action of white blood-corpuscles or upon the phenomena of phagocytosis, while a frog's heart exposed to the rays for several hours appeared to undergo no alteration of movement.†

Nutrition.

Lépine and Boulud‡ have found that marked glycolysis was produced by the action of the rays upon defibrinated dog's blood, and that the power of the amylolytic ferment of the pancreas was increased.

* *Medical Press and Circular*, September 1, 1897, p. 212.
† *Lancet*, May 29, 1897, p. 1505.
‡ *Lyon Médical*, December 20, 1903, p. 950.

Mechanics of Digestion.

By introducing little paste pellets of bismuth subnitrate with starch into the stomach of animals Dr. W. B. Cannon,* of Harvard, has succeeded in demonstrating that the food particles in the neighbourhood of the pylorus retain their relative position for a considerable period of time. The inference is drawn that salivary digestion may be allowed to continue here without the interference of the acid gastric juice.

* *Journal of the American Medical Association*, March 21, 1903, p. 750.

I. THE RAYS IN VETERINARY SURGERY*

A GOOD deal of work has been done with the Röntgen rays in veterinary practice by Professor Hobday and others.†

The horse's hoof he found to be readily penetrable by the rays, so that a foreign metallic body, such as a misdirected nail, could be at once detected in that region, and he obtained excellent radiograms of dogs and cats suffering from various accidents. In the *Veterinarian* for September, 1896, Professor Hobday and Mr. Johnson wrote: 'In conclusion, the authors consider that the Röntgen rays can be successfully applied to the smaller animals without much difficulty. In the horse the mechanical difficulties of restraint have been successfully overcome. . . . For diagnosis of abnormalities of the bones of the limbs, such as suspected fracture of the pastern, small ringbone, sidebone, or foreign body in the hoof, the results demonstrate that this method can be applied successfully. With the bones of the neck, too, no great difficulty is anticipated.'

Since that time further work has been done by Major Frederick Smith, of the Army Veterinary Department, and Professor Hobday, the results being to effect a great reduction of exposure and to bring the method within more practical limits, also to show the value of the screen in certain cases.

The main difficulties have arisen in connection with the diagnoses of spavin and navicular disease. In spavin the closeness of the bones to each other, their curved articular surfaces, the presence of overhanging ridges so frequently found in normal

* This section has been kindly revised by Professor F. Hobday, of the Royal Veterinary College, London.

† *Journal of Comparative Pathology and Therapeutics*, vol. ix., p. 58; *Veterinary Record*, September, 1896.

hocks, together with the fact that the bones are placed one behind the other, made the task of unusual difficulty.

In navicular disease the experimenters have up to the present had

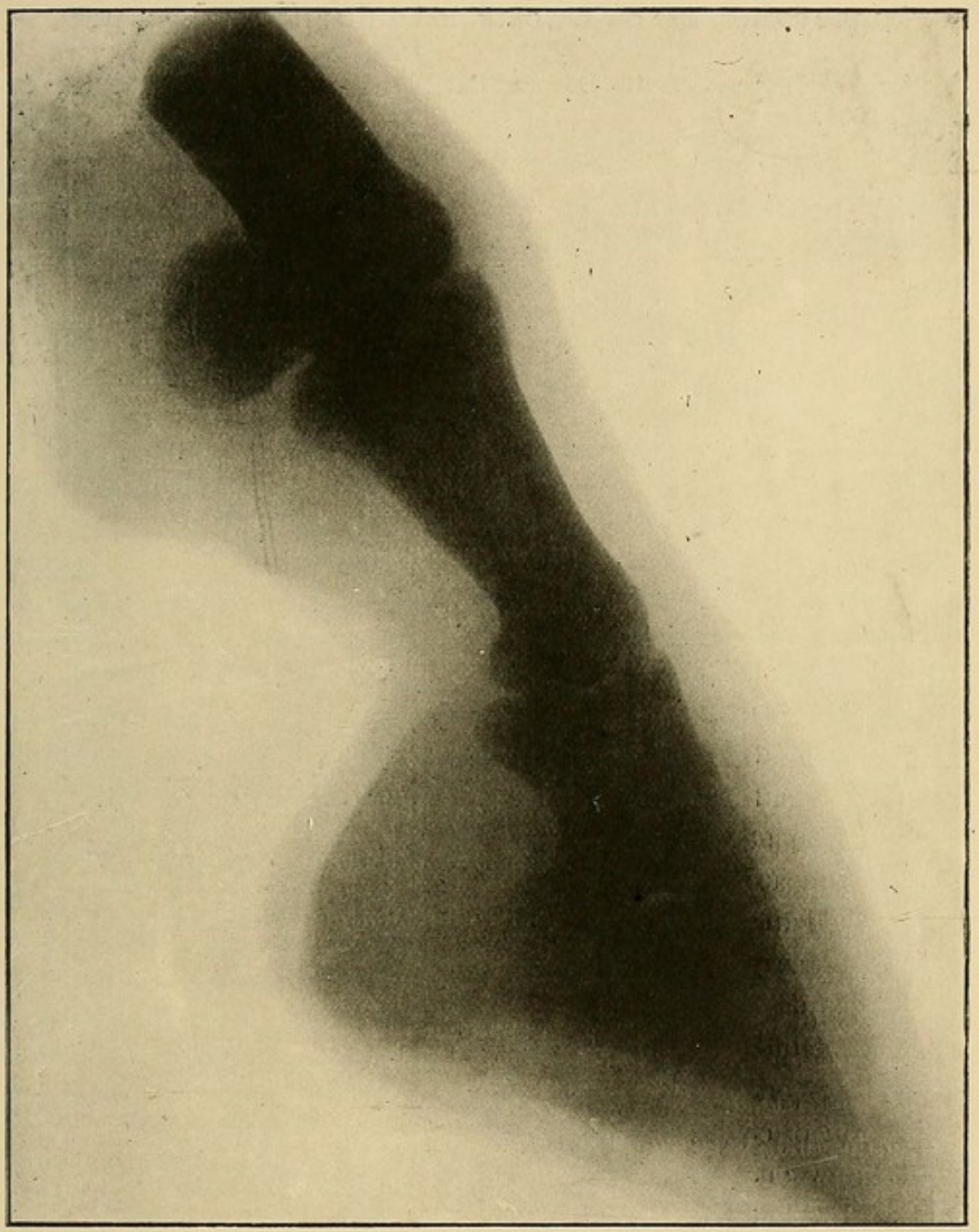


FIG. 172.—PHALANGES OF HORSE'S HOOF (60 seconds exposure).

By A. W. Isenthal.

to acknowledge failure, as the position of the bone in regard to its surroundings and the nature of the lesion render attempts to further diagnosis by the application of the *x*-rays abortive.

Professor Hobday has published some interesting radiograms illustrating various abnormal conditions in cats and dogs.* One of them shows a normal pelvis in a toy bull bitch, which had not been used for breeding because of a supposed deformity. The doubt being disproved of, the owner obtained a fine litter of puppies.

* 'Surgical Diseases of the Dog and Cat,' F. Hobday, 2nd edition, Baillière, London, 1905.

APPENDIX

A NEW FORM OF RADIATION

BEING A PRELIMINARY COMMUNICATION TO THE WURZBURG PHYSICO-MEDICAL SOCIETY BY PROFESSOR WILHELM KONRAD RÖNTGEN, DECEMBER, 1895.

1. IF we pass the discharge from a large Ruhmkorff coil through a Hittorf or a sufficiently exhausted Lenard, Crookes, or similar apparatus, and cover the tube with a somewhat closely-fitting mantle of thin black cardboard, we observe in a completely-darkened room that a paper screen washed with a barium-platino-cyanide lights up brilliantly and fluoresces equally well whether the treated side or the other be turned towards the discharge-tube. Fluorescence is still observable 2 metres away from the apparatus. It is easy to convince one's self that the cause of the fluorescence is the discharge from the apparatus, and nothing else.

2. The most striking feature of this phenomenon is that an influence capable of exciting brilliant fluorescence is able to pass through the black cardboard cover, which transmits none of the ultra-violet rays of the sun or of the electric arc, and one immediately inquires whether other bodies possess this property. It is soon discovered that all bodies are transparent to this influence, but in very different degrees. A few examples will suffice. Paper is very transparent ;* the fluorescent screen still lighted up brightly when held behind a bound volume of 1,000 pages ; the printer's ink offered no perceptible obstacle. Fluorescence was also noted behind two packs of cards ; a few cards held between tube and screen made no perceptible difference. A single sheet of tinfoil is scarcely noticeable; only after several layers have been laid on top of each other is a shadow clearly visible on the screen. Thick blocks of wood are also transparent ; fir-planks from 2 cm. to 3 cm. thick are but slightly opaque. A film of aluminium about 15 mm. thick weakens the effect considerably, though it does not entirely destroy the fluorescence. Several centimetres of vulcanized indiarubber let the rays through.† Glass plates of the same thickness behave in a different way, according as they contain

* By the 'transparency' of a body I denote the ratio of the brightness of a fluorescent screen held right behind the body in question to the brightness of the same screen under exactly the same conditions, but without the interposing body.

† For brevity's sake I should like to use the expression 'rays,' and to distinguish these from other rays I will call them 'x-rays.'

lead (flint glass) or not; the former are much less transparent than the latter. If the hand be held between the tube and the screen, the dark shadow of the bones is visible within the slightly dark shadow of the hand. Water, bisulphide of carbon, and various other liquids behave in this respect as if they were transparent. I was not able to determine whether water was more transparent than air. Behind plates of copper, silver, lead, gold, platinum, fluorescence is still clearly visible, but only when the plates are not too thick. Platinum 0·2 mm. thick is transparent; silver and copper sheets may be decidedly thicker. Lead 1·5 mm. thick is practically opaque, and was on this account often made use of. A wooden rod of 20 by 20 mm. cross-section, painted with white lead paint on one side, behaves in a peculiar manner. When it is interposed between apparatus and screen it has almost no effect when the x-rays go through the rod parallel to the painted side, but it throws a dark shadow if the rays have to traverse the paint. Very similar to the metals themselves are their salts, whether solid or in solution.

3. These and other experimental results led to the conclusion that the transparency of different substances of the same thickness is mainly conditioned by their density; no other property is in the least comparable with this.

The following experiments, however, show that density is not altogether alone in its influence. I experimented on the transparency of nearly the same thickness of glass, aluminium, calcspar, and quartz. The density of these substances is nearly the same, and yet it was quite evident that the spar was decidedly less transparent than the other bodies, which were very much like each other in their behaviour. I have not observed calcspar fluoresce in a manner comparable with glass.

4. With increasing thickness all bodies become less transparent. In order to find a law connecting transparency with thickness, I made some photographic observations, the photographic plate being partly covered with an increasing number of sheets of tinfoil. Photometric measurements will be undertaken when I am in possession of a suitable photometer.

5. Sheets of platinum, lead, zinc, and aluminium were rolled until they appeared to be of almost equal transparency. The following table gives the thicknesses in millimetres, the thicknesses relative to the platinum sheet, and the density:

Thickness.	*Relative Thickness.*	*Density.*
Pt 0·018	1	21·5
Pb 0·05	3	11·3
Zn 0·1	6	7·1
Al 3·5	200	2·6

It is to be observed in connection with these figures that, although the product of the thickness into density may be the same, it does not in any way follow that the transparency of the different metals is the same. The transparency increases at a greater rate than this product decreases.

6. The fluorescence of barium-platino-cyanide is not the only recognisable phenomenon due to *x*-rays. It may be observed, first of all, that other bodies fluoresce—for example, phosphorus, calcium compounds, uranium glass, ordinary glass, calcspar, rock salt, etc.

Of especial interest in many ways is the fact that photographic dry plates show themselves susceptible to *x*-rays. We are thus in a position to corroborate many phenomena in which mistakes are easy, and I have, whenever possible, controlled each important ocular observation on fluorescence by means of photography. Owing to the property possessed by the rays of passing almost without any absorption through thin sheets of wood, paper, or tinfoil, we can take the impressions on the photographic plate inside the camera or paper cover whilst in a well-lit room. In former days this property of the ray only showed itself in the necessity under which we lay of not keeping undeveloped plates, wrapped in the usual paper and board, for any length of time in the vicinity of discharge-tubes. It is still open to question whether the chemical effect on the silver salts of photographic plates is exercised directly by the *x*-rays. It is possible that this effect is due to the fluorescent light which, as mentioned above, may be generated on the glass plate, or perhaps on the layer of gelatine. 'Films' may be used just as well as glass plates.

I have not as yet experimentally proved that the *x*-rays are able to cause thermal effects, but we may very well take their existence as probable, since it is proved that the fluorescent phenomenon alters the properties of *x*-rays, and it is certain that all the incident *x*-rays do not leave the bodies as such.

The retina of the eye is not susceptible to these rays. An eye brought close up to the discharge apparatus perceives nothing, although, according to experiments made, the media contained in the eye are fairly transparent.

7. As soon as I had determined the transparency of different substances of various thicknesses, I hastened to ascertain how the *x*-rays behaved when passing through a prism—whether they were refracted or no. Water and carbon disulphide, in prisms of about 30° refractive angle, showed neither with the fluorescing screen nor with the photographic plate any sign of refraction. For purposes of comparison the refraction of light rays was observed under the same conditions; the refracted images on the plate were respectively about 10 mm. and 20 mm. from the non-refracted one. With an aluminium and a vulcanized rubber prism of 30° angle I have obtained images on photographic plates in which one may perhaps see refraction. But the matter is very uncertain, and even if refraction exists, it is so small that the refractive index of the *x*-ray for the above materials can only be, at the highest, 1·05. Using the fluorescent screen,

I was unable to discover any refraction at all in the case of the aluminium and the rubber prism.

Researches with prisms of denser metals have yielded up to now no certain results, on account of the small transparency, and consequently lessened intensity, of the transmitted ray.

In view of this state of things, and the importance of the question whether x-rays are refracted on passing from one medium to another, it is satisfactory to find that this question can be attacked in another way than by means of prisms. Finely-powdered substances in sufficient thicknesses allow only a very little of the incident light to pass through, and that is dispersed by refraction and reflection. Now, powdered substances are quite as transparent to x-rays as are solid bodies of equal mass. Hence, it is proved that refraction and regular reflection do not exist to a noticeable degree. The experiments were carried out with finely-powdered rock salt, with powdered electrolytic silver, and with the zinc powder much used in chemical work. In no case was any difference observed between the transparency of the powdered and solid substance, either when using the fluorescent screen or the photographic plate.

It follows, from what has been said, that the x-rays cannot be concentrated by lenses; a large vulcanized rubber and glass lens were without influence. The shadow of a round rod is darker in the middle than at the edge; that of a tube filled with any substance more transparent than the material of the tube is lighter in the middle than at the edge.

8. The question of the reflection of the x-rays is settled in one's mind by the preceding paragraphs, and no appreciable regular reflection of the rays from the substances experimented with need be looked for. Other investigations, which I will describe here, lead to the same result. Nevertheless, an observation must be mentioned which at first sight appears to contradict the above statement. I exposed a photographic plate to the x-rays, protected against light rays by black paper, the glass side being directed towards the discharge-tube. The sensitive layer was nearly covered, star fashion, with blanks of platinum, lead, zinc, and aluminium. On developing the negative, it was clearly noticeable that the blackening under the platinum, lead, and especially under the zinc, was greater than in other places. The aluminium had exercised hardly any effect. It appeared, therefore, that the three above-mentioned metals had reflected the rays. Nevertheless, other causes for the greater blackening were thinkable, and in order to make sure I made a second experiment, and laid a piece of thin aluminium, which is opaque to ultra-violet rays, though very transparent to x-rays, between the sensitive layers and the metal blanks. As again much the same result was found, a reflection of x-rays by the above-mentioned metals was demonstrated. But if we connect these facts with the observation that powders are quite as transparent as solid bodies, and that, moreover, bodies with rough surfaces are, in regard to the transmission of x-rays, as well as in the experiment

just described, the same as polished bodies, one comes to the conclusion that regular reflection, as already stated, does not exist, but that the bodies behaved to the x-rays as muddy media do to light.

Again, as I could discover no refraction at the point of passage from one medium to another, t would seem as if the x-rays went through all substances at the same speed, and that in a medium which is everywhere, and in which the material particles are embedded, the particles obstruct the propagation of the x-rays in proportion to the density of the bodies.

9. Hence it may be that the arrangement of the particles in the bodies influences the transparency; that, for example, equal thicknesses of calcspar would exhibit different transparencies, according as the rays were in the direction of the axis or at right angles to it. Researches with calcspar and quartz have yielded a negative result.

10. It is well known that Lenard, in his beautiful investigation on Hittorf cathode rays passed through thin aluminium-foil, came to the conclusion that these rays were actions in the ether, and that they pass diffusively through all bodies. I have been able to say the same about my rays.

In his last work Lenard has determined the absorption coefficient of various bodies for cathode rays, and among other things for air atmospheric pressure at 4·1, 3·4, 3·1, per centimetre, and found it connected with the exhaustion of the gas contained in the discharge apparatus. In order to estimate the discharge pressure by the spark-gap method, I used in my researches almost always the same exhaustion. I succeeded with a Weber photometer (I do not possess a better one) in comparing the intensity of the light of my fluorescing screen at distances of about 100 mm. and 200 mm. from the discharge apparatus, and found in the case of three tests agreeing well with one another, that it varied very nearly inversely as the square of the distance of the screen from the discharge apparatus. Hence the air absorbs a very much smaller fraction of the x-rays than of the cathode rays. This result is also quite in agreement with the result previously mentioned, that the fluorescing light was still observable at a distance of 2 metres from the discharge-tube.

Other bodies behave generally like air—that is to say, they are more transparent for x-rays than for cathode rays.

11. A further noteworthy difference in the behaviour of cathode rays and x-rays consists in the fact that, in spite of many attempts, I have not succeeded, even with very strong magnetic fields, in deflecting x-rays by a magnet. The magnetic deflection has been, up to now, a characteristic mark of the cathode ray; it was, indeed, noticed by Hertz and Lenard that there were different kinds of cathode rays, 'distinguishable from one another by their phosphorescing powers, absorption and magnetic deflection,' but a considerable deflection was nevertheless observed in all cases, and I do not think this characteristic will be given up without overwhelming evidence.

12. After experiments bearing specially on this question, it is certain that the spot on the wall of the discharge apparatus which fluoresces most decidedly must be regarded as the principal point of the radiation of the *x*-rays in all directions. The *x*-rays thus start from the point at which, according to the researches of different investigators, the cathode rays impinge upon the wall of the glass tube. If one deflects the cathode rays within the apparatus by a magnet, it is found that the *x*-rays are emitted from another spot — that is to say, from the new termination of the cathode stream.

On this account, also, the *x*-rays, which are not deflected, cannot merely be unaltered reflected cathode rays passing through the glass wall. The greater density of the glass outside the discharge-tube cannot, according to Lenard, be made responsible for the great difference in the 'deflectability.'

I therefore come to the conclusion that the *x*-rays are not identical with the cathode rays, but that they are generated by the cathode rays at the glass wall of the discharge apparatus.

13. This excitation does not take place only in glass, but also in aluminium, as I was able to ascertain with an apparatus closed by a sheet of aluminium 2 mm. thick. Other substances will be studied later on.

14. The justification for giving the name of 'rays' to the influence emanating from the wall of the discharge apparatus depends partly on the very regular shadows which they form when one interposes more or less transparent bodies between the apparatus and the fluorescing screen or photographic plate. Many such shadow-pictures, the formation of which possesses a special charm, I have observed—some photographically. For example, I possess photographs of the shadow of the profile of the door separating the room in which was the discharge apparatus from the room in which was the photographic plate; also photographs of the shadows of the bones of the hand, of the shadow of a wire wound on a wooden spool, of a weight enclosed in a small box, of a compass in which the magnetic needle is completely surrounded by metal, of a piece of metal the lack of homogeneity of which was brought out by the *x*-rays, etc.

To show the rectilinear propagation of the *x*-rays there is a pinhole photograph, which I was able to take by means of the discharge apparatus covered with black paper. The image is weak, but unmistakably correct.

15. I looked very carefully for interference phenomena with *x*-rays, but unfortunately, perhaps on account of the small intensity of the rays, without success.

16. Researches to determine whether electrostatic forces affect *x*-rays in any way have been begun, but are not completed.

17. If we ask what *x*-rays—which certainly cannot be cathode rays—really are, we are led at first sight, owing to their powerful fluorescing and chemical properties, to think of ultra-violet light. But we imme-

diately encounter serious objections. If x-rays be in reality ultra-violet light, this light must possess the following characteristics:

(*a*) It must show no perceptible refraction on passing from air into water, bisulphide of carbon, aluminium, rock salt, glass, zinc, etc.

(*b*) It must not be regularly reflected to any appreciable extent from the above bodies.

(*c*) It must not be polarizable by the usual means.

(*d*) Its absorption must not be influenced by any of the properties of substances to the same extent as it is by their density.

In other words, we must assume that these ultra-violet rays behave in quite a different manner from any infra-red, visible, or ultra-violet rays hitherto known. I could not bring myself to this conclusion, and I have, therefore, sought another explanation.

There seems at least some connection between the new rays and light rays in the shadow-pictures and in the fluorescing and chemical activity of both kinds of rays. Now, it has long been known that, besides the transverse light vibrations, longitudinal vibrations might take place in the ether, and, according to the view of different physicists, must take place. Certainly their existence has not up till now been made evident, and their properties have not, on that account, been experimentally investigated.

May not the new rays be due to longitudinal vibrations in the ether?

I must admit that I have put more and more faith in this idea in the course of my research, and I therefore advance that surmise, although I know that such an explanation requires further corroboration.

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